Material Culture in Medieval Europe

Papers of the 'Medieval Europe Brugge 1997' Conference
Volume 7

edited by
Guy De Boe & Frans Verhaeghe

I.A.P. Rapporten 7

Zellik
1997

I.A.P. Rapporten

7

I.A.P. Rapporten

uitgegeven door / edited by

Prof. Dr. Guy De Boe

Material Culture
in Medieval Europe

Papers of the 'Medieval Europe Brugge 1997' Conference
Volume 7

edited by
Guy De Boe & Frans Verhaeghe

I.A.P. Rapporten 7

Zellik
1997

Een uitgave van het

Published by the

Instituut voor het Archeologisch Patrimonium
Institute for the Archaeological Heritage

Wetenschappelijke instelling van de

Scientific Institution of the

Vlaamse Gemeenschap
Departement Leefmilieu en Infrastructuur
Administratie Ruimtelijke Ordening, Huisvesting
en Monumenten en Landschappen

Flemish Community
Department of the Environment and Infrastructure
Administration of Town Planning, Housing
and Monuments and Landscapes

Doornveld
Industrie Asse 3 nr. 11, Bus 30
B -1731 Zellik - Asse
Tel: (02) 463.13.33 (+ 32 2 463 13 33)
Fax: (02) 463.19.51 (+ 32 2 463 19 51)

DTP: Arpuco.
Secr.: M. Lauwaert & S. Van de Voorde.

ISSN 1372-0007
ISBN 90-75230-08-7
D/1997/6024/7

07 MATERIAL CULTURE - MATERIËLE CULTUUR - CULTURE MATÉRIELLE - MATERIELLE KULTUR

was organized by
werd georganiseerd door
fut organisée par
wurde veranstaltet von

Alan Vince
Frans Verhaeghe

Preface

Material culture is of course a central issue to any form of archaeological endeavour as 'material things' and the 'history of things' manufactured, fashioned or at least influenced by humans constitute both the main sources and the direct subject of archaeological studies. The concept is not limited to smaller or moveable objects or classes of objects such as ceramics, jewellery, dress accessories, tools, glass vessels, combs in bone or ivory and many others. Castles, monasteries, villages and towns and even landscapes and the environments as a whole can be considered as 'objects' or even as 'artefacts' totally or in part 'created' by humans and therefore integral parts of material culture. The same is of course also valid for works of art, food, material living standards and many other aspects of the worlds past and present.

In addition, material culture is not a passive but an active component of these past and present worlds. More particularly, it is active in several major ways. It is all too often forgotten that artefacts of any kind always influence the later development both of the same type of artefacts and of other classes of objects. In this sense, all components of material culture are interactive with one another. Furthermore, they also influence human behaviour and human perception of the world and of society. In addition, artefacts are used in strategies of social reproduction and manipulation of the world and of society. And finally, the meanings of artefacts change depending on the context, *i.e.* through time, space and social context. It is through interpretation – whatever ideological approach is used or whatever subject is focused on – that archaeologists can try and decode the human behaviour and perceptions that are reflected in all possible remains and traces of the material past.

All this means that it can reasonably be argued that any conference on medieval and early modern archaeology concerns the totality of the material world because no part of that past (and present) material culture can hardly be divorced and isolated from the totality of that material culture or for that matter from the individuals or the society that created and manipulated it.

In practice, however, many archaeologists of medieval and early modern times tend to limit the application of the concept of material culture to the smaller, moveable objects, often also denoted as 'finds'. Material culture then encompasses mainly smaller artefacts of every kind, generally grouped in main classes such as ceramics, metal, glass, skeletal materials, wood, textiles, etc. The organisers of the MEDIEVAL EUROPE BRUGGE 1997 and the editors of the present volume have adhered to this approach mainly because of sheer practical reasons and because no other and better terminology is yet available.

The archaeological study of medieval and later material culture in the restricted sense of the term already has a fairly long tradition. It developed very much along lines set by the approaches used in other and older branches of archaeology. Not in the least because of the basic need to identify and group the objects in manageable units and to assess their chronological development, typology and chronological sequencing have always played a major part in this kind of work and they continue to do so. This is not all too surprising as ever more and ever new collections of finds come to light. Another topic which has nearly always been in the limelight in this context is that of technological features and developments. And as the present collection of papers demonstrates, this too remains a subject of interest, though the emphasis has now moved from the analysis and description of the technical features of the finds to the study and discussion of technical production processes. At the same time, the natural science work – particularly in terms of analysis work – has grown more prominent, providing absolutely essential information which in turn helps with the identification of resources and technical production processes as well as with other issues such as chronology, provenancing and trade. Finally, other 'historical' sources – in the broadest possible meaning of the term and including ethnographical and iconographic sources as well as experimental archaeology – have equally been called in to help not only with chronology (particularly for the later Middle Ages and Early Modern Times) but also with production technologies, uses and functions of the objects and even – be it to a much more limited extent – their social context.

On the whole, however, much of the work on finds remains of a somewhat descriptive nature, at least in Europe (and notwithstanding a few notable exceptions). The large offer of papers related to material culture – in the sense used here – for the MEDIEVAL EUROPE BRUGGE 1997 conference does illustrate the vitality of the subject and the continuing interest in finds of all kinds and in the issues they raise. They also illustrate the continuing emphasis on technological problems and production processes.

But this vitality should not blind us to some apparent trends and problems which seem to affect the field in more recent years. The already mentioned emphasis on descriptive work is to some extent understandable as the need for basic data and for the adequate management and use of the information concealed in the rapidly growing mass of finds remains of the utmost importance. In quite a few cases, however, there is little opportunity for work beyond that descriptive phase. The most notorious example in this respect is the simple typological or techno-typological classification of ceramics, with a comment on the possible or probable origins of the groups and a deliberate emphasis on chronology, basically reducing the pottery to an indicator of a chronological nature and disregarding the potential of these – and other – finds as sources for more complex questions related to behavioural and social patterns. In addition, the increasing pressures of rescue work and managing the archaeological heritage often leave little time for more sophisticated discussion of the finds in terms of issues above and beyond typology and chronology. A related and equally dangerous trend is that it seems to become increasingly difficult to keep up with the growing mass of finds: the backlog remains a major problem, particularly as the costs of storing the finds raise the delicate issue of curation of the collections. Equally dangerous is that most of the work on finds does not lead to a structural consolidation of the knowledge thus built up, which in turn leads to recurrent losses of expertise and sometimes even to reinventing the wheel. Finally, the lack of interest in any form of theoretical work which seems to affect large segments of mainly European – particularly medieval and early modern – archaeology does not help either as it may – together with external pressures of a financial and practical nature which constrict much of present-day archaeological work – strengthen the trend towards simpler descriptive work. This means that the huge potential of archaeological finds is not fully realized and that (medieval and early modern) archaeology is not fully responding to the justified expectations of historians, anthropologists and other human or social scientists. It may be argued that the more sophisticated interpretative work will eventually be carried out – in the near or far future. But it remains to be seen how valid this reasoning really is. Indeed, it remains to be demonstrated that this will really happen in the future. Furthermore, it should not be forgotten that files and collections are often subject to subtle or sometimes even less subtle forms of erosion, leading to a loss of potential information. And in addition, relegating the more sophisticated work to an – at best uncertain – future also hinders progress: it does not help with the identification of the kinds of information needed or with the many interpretative questions still open or indeed yet to be recognized, thus at the same time leaving little room for suitable collecting and sampling strategies in the field.

The situation may not be as dramatic as this paragraphs suggests, but the editors of the present volume feel that the dangers are very real and should be kept in mind.

Still, the interest in finds and in material culture (even in the restricted sense in which the notion is used here) is not flagging, judging from the large number of papers offered for presentation in the section 07 under the general heading *Material culture: production and consumption - Culture matérielle : production and consommation - Materielle Kultur: Produktion and Verbrauch - Materiële cultuur: productie en consumptie* at the MEDIEVAL EUROPE BRUGGE 1997 international conference on medieval and later archaeology which took place in Brugge, Belgium, on 1 through 4 October 1997. The section has been organized by Alan Vince (Lincoln, United Kingdom) and Frans Verhaeghe (F.W.O. and Free University of Brussels, Belgium). For sheer practical reasons, the section grouped a number of contributions related to different kinds of finds, their production and technological production processes and developments, and their consumption.

The present volume offers a collection of preprinted papers, a number of which were presented orally and debated during the sessions of section 07.

Unfortunately, a number of contributors to this section did not submit a text in time for inclusion in the present volume while other colleagues could not attend and present their contribution. In a few cases, texts were graciously made available for inclusion in the present volume but could not be presented orally due to the large offer of papers or because the colleagues could not attend the conference. All this explains why the general structure and the contents of the present volume do not conform in all details to the programme of the conference. Nevertheless, the volume has been organized keeping in mind both the complexity of the subject and the general lines of the structure of section 07 of the conference as originally proposed by the organizers. The texts available for the present volume have therefore been grouped in three main sections, which at the same time largely reflect the current concerns and state of research in the archaeological study of the medieval and later finds:

- the first section groups a substantial number of papers under the general heading *Production: technology, production processes, organisation, workshops and artisans*. These papers concern a whole range of aspects directly related to the production of goods, drawing on whole range of evidence – archaeological, historical, ethnographical, natural sciences. Because of the very different accents and/ or the intertwining of a wide range of topics, it proved next to impossible to order them in terms of specific subjects such as the role of the artisan, the organisation and functioning of workshops, etc. Within this section, the contributions have been therefore been ordered according to the kind of materials discussed, *i.e.* metal, ceramics, glass, bone, wood and textiles
- Aspects of consumption are discussed in a series of contributions brought together under the heading *Consumption: patterning the use of objects*. These contributions generally raise broader issues related to patterns of consumption, ethnicity, social strategies in the use and manipulation of objects, the relations between different kinds of objects, etc.
- The section called Basic data gathering groups a series of contributions which discuss or asses the present state of primary research on specific categories or assemblages of finds, either on a regional or supra-regional level or on the level of specific sites. They have been grouped on the basis of the kind of material concerned: ceramics, glass, and metal:
- Two special workshops were organized and focused on specific categories of objects, the first one being *toys and games* and the second one being *architectural ceramics* (including tiles, bricks, stove-tiles, etc.).

Of necessity, the papers are rather short and the volume of course does not do total justice to the many studies and the wealth of other types of research work concerning material culture and finds. Thus, for instance, quite a few specific categories of finds or components of material culture as it is used here are absent from the picture. Furniture other than ceramics is but one example. Similarly, jewellery, textiles, dress accessories, wooden household utensils, food and many others are – if not totally absent – strongly under-represented. Nor does the volume provide a complete overview of the results attained and knowledge acquired. Nevertheless, the 50-odd papers included in the present volume emphasize the continuing importance and vitality of the study of medieval and later material culture while at the same time providing a good idea of the potential and of the present state of the work in this particular field of research. They also reflect both the complexity of the subject, the present trends and the recent developments in terms of approaches. This is even more true when the volume is considered within the context of the other volumes in the present series of volumes linked with the MEDIEVAL EUROPE BRUGGE 1997 conference and when the reader takes into account that the world of material culture is also very much present – directly or indirectly – in these other volumes. Indeed, as said earlier – and as with the other themes discussed at the Brugge conference – the subject of material culture cannot and should not be divorced from the many other concerns of medieval and later archaeology. The sheer complexity of the subject entails inevitable links with many other topics presented and discussed within the context of the other sections of the, among them trade and exchange (section 03) and environment and subsistence (section 09). Nor should the issues raised within the context of sections 10 (Method and Theory in Historical Archaeology), 05 (Art and Symbolism) or 08 (Travel Technology and Organization) be forgotten. At the same time, all the objects discussed in the present volume were part of life in the different types of settlement discussed in the other volumes of the present series. Taking into account the sheer mass of evidence and the potential information – including not only the data concerning technological developments and innovations but also those related to the social and spatial patterning and the behavioural interpretation of often though not always somewhat humbler objects – material culture (even in the restricted sense used here) deserves the effort.

Frans Verhaeghe & Guy De Boe

Thilo Rehren

Metal Analysis in the Middle Ages

Introduction

The determination of the metal content of ores is a need as old as man's encounter with extractive metallurgy. The development of a structured system of chemical methods to this end is, however, a rather recent achievement, probably not older than half a millennium. This system served in a fundamental way the development of modern scientific chemistry, together with technical expertise gathered mainly by the alchemists. The most comprehensive and non-obscure of the early sources on this subject is book VII of Georgius Agricola's opus magnum *'De re metallica libri XII'*. Here, Agricola provides us with a highly developed system, which is clearly rooted in older knowledge. What are these roots, and how deep do they reach?

While much has been written about the alchemists as inventors of analytical procedures, the role of mining and metallurgy in this context is less well studied. The aim of this paper is to point to some promising avenues of research into this field rather than to give ready-made answers. In this paper, 'analysis' is understood as any chemical method that allows the analyst to determine the metal content of a given material by treating a fraction only of the total, in a manner that is reproducible, rational and reliable. Hence, fundamentally inherent features of analysis are principles of physics, statistics and mathematics, of weighing, sampling and calculating, as developed e.g. by Nicolaus von Kues, known as Cusanus, in the middle of the 15th century. These non-chemical aspects are not, however, dealt with here.

The aim of this paper is to set the frame within which metals analysis developed in response to individual needs during the Middle Ages, eventually merging to a complex system of general coverage and validity. I would like to emphasize, however, that the following is very generalised and in part oversimplified. Both the economic and the technological aspects of mining history are much more complex than it may appear here.

The early need for analysis in metallurgy

Ancient metallurgy has many different facets, from smelting to alloying, casting and working to recycling and refining, with accordingly many different needs and skills. Analytical knowledge is particularly essential for mining and extractive metallurgy, *i.e.* the production and smelting of ore, for monetary metallurgy, for alloy control, and for the metals trade. Analysis becomes, very generally speaking, more important with an increasing variability of supply, *e.g.* through complex trade networks or changing metal sources, when experience and tradition alone are no longer a sufficient base on which to make decisions.

Mining and Extractive metallurgy: The concept of fire assay

One may think of the dawn of metallurgy as a period when rich ores were plentiful, readily available and easily accessible to early man. This golden age will not, however, have lasted for long, since we have evidence for tedious underground mining of poor ores from as early as the Chalcolithic period (Weisgerber & Pernicka 1995), and continuously since then. The quality of the ores of most metals could, however, probably be judged by eyesight alone, which will thus have been the first 'analytical' tool. Based on the experience that a mineral of a particular appearance (colour, cleavage, density, etc.) is bound to transform into copper, lead or other metal when smelted properly, the basic question in early mining was that of the richness of an ore, *i.e.* the content of rich mineral relative to waste rock, the effort necessary to get it out of the ground, moved to the smelter and complemented with charcoal.

In cases where the economically important metal was not obvious, like in argentiferous lead ores, simple experience with a particular deposit may have told whether the ore was worth mining and the additional desilverizing treatment or not. Many galenadominated deposits have irregular silver values, varying by orders of magnitude from one patch to the next (see for instance Bartels 1992). Even in such cases however, large scale, in particular state-controlled, mining operations, as with some Roman mines in Spain or Britain, may possibly have been run profitably in the long term, with rich and poor ores being mined and smelted altogether without analytical control. One has to be cautious however with this statement, since we have no indication as to what sort of quality control of the ore was done in the lead mining areas of classical Antiquity. The possibility that analytical procedures in the above-mentioned sense were used cannot be excluded, for we cannot prove the absence of something ('absence of evidence is not evidence of absence'). It seems plausible to assume that such quality control was conducted by test or trial smelts. With no clear reduction in size however this is not considered 'analysis' in the sense used here. Mining and metallurgy in Central and Western Europe apparently faded away with the decline of the Roman empire with but little continuity in north-eastern areas of Europe (Bartels 1996). This hiatus will have affected specialised techniques even more than common knowledge, and as a result we have no means to extrapolate from later periods to earlier ones.

In medieval mining, we face a very different economic situation, with predominantly small scale operations by independent miners (Bartels 1994) often without the resources to cover periods of failing income. Under such conditions, an irregular deposit could be mined only if the silver content of the ore was closely controlled, enabling the selective winning of the rich parts only and avoiding ore below the cut-off. Here at least, there clearly exists a need for some sort of analysis, but still the traditional, macroscopic methods will have been suitable to detect the rich mineral. The small size of operational units and their restricted economic possibilities will have limited the actual application of sophisticated analytical methods; analysis however developed mainly as a means to control and predict the subsequent smelting operations (Bartels, pers. comm.).

The period of mining by small groups or even by individual miners came more or less to an end in Central Europe in the late Middle Ages, marked by a widespread crisis in the mining areas like the Harz mountains, the *Erzgebirge*, etc. in the mid-14th century. The traditional system comprised self-employed miners, carrying their individual ore to the smelter and being rewarded with their individual metal. This was generally followed by a system of employed miners being paid for their work irrespective of the actual ore mined. This of course required highly organised, capital-intensive investment groups, controlling the entire system from the supply of the mining and smelting areas with consumables and auxiliary materials up to the distribution of the metal throughout Europe, often based on long-term contracts, loans and debts (Stromer 1984, 51). These entrepreneurs, often with first-hand knowledge of and experience in mining and metallurgy, of course needed reliable data on which to base their decisions on invested capital. In the course of these developments, but particularly with the decrease of rich mineral and the necessity to mine low-grade ores (Bartels 1992), analysis became more and more important also to characterise and evaluate this ore, beside its continuing role in controlling the smelting operations.

In the heyday of this system, by the time of Georgius Agricola and Lazarus Ercker in the middle of the 16th century, fire assay was obviously common practise for a wide range of minerals and rocks. L. Ercker (1580, 70) informs us that at Kuttenberg (Kutna Hora) at his time more than 200 tests for silver were done every week. Agricola devotes the entire book VII of his '*De re metallica XII libri*' to fire assay and analysis, apparently based on a bundle of somewhat earlier, but poorly organised and less comprehensive booklets (*Berg- und Probierbüchlein*) on the same topic. By then, every known substance could be analysed in any raw, intermediate or finished material. The sophisticated and elaborate level of the recipes given and the chemical methods available suggest a rich tradition and long-lasting practice. It should be mentioned, however, that Agricola deems it necessary to state explicitly that 'The method of assaying ore used by the mining people, differs from smelting only by the small amount of material used. Inasmuch as, by smelting a small quantity, they learn whether the smelting of a large quantity will compensate them for their expenditure ... Both processes, however, are carried out in the same way, for just as we assay ore in a little furnace, so do we smelt it in the large furnace. Also in both cases charcoal and not wood is burned. Moreover, in the crucible when metals are tested, be they gold, silver, copper, or lead, they are mixed in precisely the same way as they are mixed in the blast furnace when they are smelted.' (Hoover & Hoover 1912, 220-2). This virtual identity of reduced and full scale processes apparently needs repetitive explanation and stating. Shall we take it as an indication that the idea was not too old in Agricola's time but still needed to be spread, or does it just reflect the non-specialist readership aimed for by Agricola?

In terms of cognition theory, we have here a situation in which innovation was achieved by downscaling an industrial process to the laboratory, *i.e.* the analysis mimics the process.

Monetary metallurgy: The analysis of silver in copper and the liquation process

During the early stages of coinage, in the first millennium BC, the need for analysis was restricted to the determination of the silver and copper content of gold and silver alloys. For gold, a perfect method for this was found in the touchstone (Oddy 1993), in regular use until today. Later, with the debasement of silver coinage in Imperial Rome, methods were developed to extract the silver content from such alloys: not only cupellation (Bayley & Eckstein 1996), in use since the Early Bronze Age, but also a slag-forming initial raffination step to condition the scrap metal (Rehren 1997a). It would be interesting to see how commonly this raffination and refining was done by the Roman mints, and how the debasement of coinage was controlled. Did they just add more base metal when remelting old coinage, or had they to refine the silver first to produce a new alloy by fusing weight amounts of pure silver and copper/bronze? The variability in composition and fineness of 3rd and 4th century debased coinage (see for instance King & Northover 1993) points to the first solution rather than to a closely controlled procedure.

During the late 15th and early 16th century, the liquation process was developed to extract small amounts of silver (below the one percent level) from raw copper metal (Suhling 1976). Stromer (1995) relates the development of this highly sophisticated process to the ability of late medieval (mid-15th century?) mint masters, experienced in the analysis of coins for precious metals. While Stromer shows this by demonstrating that the first liquation factories were established and run by mint masters, and by the introduction of legal regulations trying to suppress the extraction of copper coins from the circulating currency for liquation, there is also a reasonable metallurgical link.

The method to analyse coins for silver could only be by cupellation, *i.e.* by melting of the metal with an excess of lead which takes up all silver present, followed by a hot oxidation of this cupriferous lead to lead and copper oxide, 'litharge', which takes all the impurities with it, leaving only the noble silver (and gold) in the metallic state. With major copper contents in the metal however, this millennia-old, highly effective - even for modern standards - quantitative method suffers from serious problems due to the loss of silver, dissolved into copper oxide, into the litharge (Bayley & Eckstein 1996). Therefore, even silver-rich copper ore or metal cannot be satisfactorily worked for silver. In fire assay, a huge excess of lead (about four to five times as much lead as copper metal) is used to obtain reliable results: an impossible strategy in the case of mass production. In the liquation process, this problem is overcome by separating the argentiferous lead from the copper in the metallic state while simultaneously all the silver is transferred from the copper to the lead phase, before the lead only is subjected to cupellation.

To transfer this process from the individual coin scale to the massive, raw copper scale, it is necessary to realise the general identity of small-scale and large-scale processes. Who is more liable to develop this concept than mint masters, used to splitting huge metal charges into small individual pieces of identical composition, *i.e.* coins? With a certain coin composition required, only a few coins of each issue had to be tested by analyses to check for quality and homogeneity of the entire series. Rethinking this principle from the other end automatically leads to the idea of a 'sample' as being representative of the whole, one of the basics of analysis as outlined above. When melting copper coins in a crucible with added lead metal, the mutual immiscibility of the two metals in the solid state one day must have become obvious: either by accident or by experimentation. Who was the first to draw the crucial conclusions from this?

In terms of epistemology, it is noteworthy that in this case we have innovation by upgrading a laboratory method to an industrial process, *i.e.* exactly the other way around when compared to the previous example.

Metals trade: cupellation of lead

One of the most important auxiliary materials in extractive silver metallurgy has been lead; the Phoenicians already imported lead to smelt lead-deficient silver ores on the Iberian Peninsula, as probably did the Romans when they took over the mines in southern Spain. During the Middle Ages, the rich silver ores mined in Central Europe also required tremendous amounts of lead to be smelted and refined, often beyond the natural lead content of the mineral itself. We are well informed on the late medieval and early modern lead trade, with ten of thousands of hundred-weights of lead per year being transported from Poland, Goslar, Westfalia and even England to the mining centres in Saxony, Bohemia and Hungary (see the cumulative work of Molenda, Kraschewski, Blanchard, Bartels and others). Usually, this imported lead came from deposits low in silver, like in Westfalia, or even virtually silver free (Karinthia for example). Other lead mines, however, produced metal that in itself contained almost economically extractable amounts of silver, and this silver was regularly included in the price calculations for the lead: beside taxes, tariffs, etc. (Kraschewski 1990, 15). The metal price was usually fixed in long-term contracts. Was the supposed silver content just fixed once, or to which extend was it regularly controlled over the duration of the contract? The silver content may initially have been known from experience, or it could have been determined by 'trial smelts', *i.e.* smelting operations on a scale of 1:1. During the 16th century at the latest, certainly small scale samples were taken and analysed on the 'test' or cupel. In any case, the figure had to be determined on a regular, reliable and reproducible basis, trustworthy for both the buyer and the seller. How far can this price factor, evident from contracts, tax registers, etc., be traced back to the Middle Ages?

Alloy control: The analysis of lead and zinc in brass making

A situation very different from the abovementioned one prevails in the case of brass. This predominant copper alloy of the Middle Ages is essentially composed of copper and zinc, the latter being unknown as a metal in Europe prior to the 16th century and not frequently available prior to the 18th century. Accordingly, brass could not be produced by fusing the metals together like in the case of bronze, but was made by treating copper metal with galmei, a pale, earthy ore rich in zinc carbonate. Through much of history, brass making was hence understood as colouring the copper, rather than as alloying. This misconception finds its early expression in the – false – Roman interpretation of the originally Greek work 'ορει-χαλκος' (copper of the mountain) as '*aurichalcum*' (golden copper), and is later followed also by the medieval metallurgists. Alloy control must have been difficult: how to analyse for an unknown substance?

Here, medieval analysis clearly reached its limit. None of the contemporary sources provides us with any means to determine the zinc content in brass, and it is probably only Lazarus Ercker in the mid-16th century who realises the relation between '*Ofengalmey*', condensed fumes of zinc and lead oxides in the upper parts of copper smelting furnaces, and a strange metallic substance (called '*Contrafeht*' by him) dripping from some furnaces, which can be used for making brass! Though the increase of weight in brass production was recognised soon afterwards (Löhneyß 1617), we have no indication whether this was used to control the quality of the brass making process, or to analyse the zinc content of given brass, *e.g.* by determining the loss in weight when melting the alloy under slightly oxidising conditions.

An early example of medieval methods for the determination of the composition of copper is given by Theophilus, who not only describes how to produce brass, but also informs us that lead-rich brass is less suitable for gilding, and hence suggests that the copper should be refined before it is used in brass making. Though the 'analytical' technique used is not based on chemical methods, but on the working behaviour of the metal, the refining procedure is a proper chemical process. He advises to melt the copper in an open clay-clad iron pan and to direct a blast of air over the liquid metal. When the lead starts burning, wood ash is to be added to bind the lead oxide and to facilitate its mechanical removal. The refined copper then had to be tested again, and the refining repeated if necessary (Hawthorne & Smith 1963, 144-5). It is certainly easier for Theophilus to judge the quality of a metal by cold working than by melting it and to observe the formation of a slag or dross. The fundamental experience and insight into metal chemistry , necessary for the development of chemical analysis during later centuries, is, however, apparently present already at the turn of the millennium. The description given by Theophilus finds its precise archaeological confirmation in slags and crucibles from two sites at Dortmund (Rehren *et al.* 1993) and Soest (Rehren in prep.), both dated to the late first millennium AD.

It is not only the particular process that is of importance in our context, but the very different concept here as opposed to the Roman view of materials. The different degrees of suitability of various kinds of copper for brass making has been known already to Pliny. His copper types, named after the mining company where the copper was derived from, are in a clear order of quality, which indicates good observation. However, no means are given to manipulate the quality, and such means were apparently not only not known, but almost inconceivable: the best types of copper are long since exhausted, and one has to cope with the material presently available (Plinius 1985, 9). The medieval concept is significantly different: the material is not chosen passively, but consciously conditioned for the intended purpose!

A juxtaposition of alchemy and metallurgy

The development of a complex and versatile system like analytical chemistry with all its inherent new principles and concepts is not the achievement of one man, and not even possible within just one generation or faculty. Beside metallurgy, fundamental input came from other applied crafts and fields like early pharmacy, but also the arts and even from the much different, theory-based world of alchemy. Though an adequate discussion of the role of alchemy for the development of analytical chemistry (Lazarus Ercker [1580, 42] for instance states: '*Das Probieren ist eine gar herrliche, alte und nützliche Kunst, erfunden vor langen Zeiten ... von den Alchimisten*') is far beyond the aim of this paper, its position in relation to early metallurgy shall be considered here briefly.

The determination of the presence of a particular metal (qualitative analysis) and its relative concentration (quantitative analysis) are fundamental issues in alchemy, when the quality and 'quintessence' of a metal has to be judged, and the results of attempted transmutations have to be checked. This analytical approach closely matched the profane metallurgical needs, and much of the practical methods and recipes later used widely in metallurgy were originally developed and refined by alchemists. Major discrepancies however remained insurmountable. Alchemical work usually was deeply based in a theory fundamentally different from our present understanding of the material world, and in unconscious controversy to the methods used to prove its attempted working. Accordingly, theoretical considerations and practical observations were rarely compatible. In contrast, the metallurgist followed a mere practical approach, much less concerned with philosophical issues. Accordingly, he was much more bound first to realise and later to rely on the reproducibility of his work. Hence, it is no surprise that the principles of modern experimental and analytical chemistry owe much more to the early people involved in the applied crafts than is often assumed. The relation between the alchemist and the metallurgist was not, however, always free of controversy. Agricola, one of the foremost representatives of the Renaissance scholars, clearly expresses his low opinion of the alchemists:

'These masters teach their disciples that the base metals, when smelted, are broken up; they also teach the methods by which they reduce them to the primary parts and remove whatever is superfluous in them, and by supplying what is wanted make out of them the precious metals – that is, gold and silver, – all of which they carry out in a crucible. Whether they can do these things or not I cannot decide; but, seeing that so many writers assure us with all earnestness that they have reached that goal for which they aimed, it would seem that faith might be placed in them; yet also seeing that we do not read of any of them ever having become rich by this art, nor do we now see them growing rich, although so many nations everywhere have produced, and are producing, alchemists, and all of them are straining every nerve night and day to the end that they may heap a great quantity of gold and silver, I should say the matter is dubious' (Hoover & Hoover 1912, xxviii).

There were however also fruitful links between alchemy and metallurgy, particularly when both interests met in one person. An example of this is Wolfgang II of Hohenlohe, who's biography is given by Weyer (1992). Wolfgang possessed his own laboratory in the basement of his castle, where he found distraction from his daily duties in alchemical work. Though the idea of making gold by transmutation was not his main concern, he did not entirely ignore it either. Accordingly, Wolfgang was well experienced in cupellation techniques, and was asked at several occasions by a relative of his to test ore samples for gold and silver.

The archaeological evidence

The examples given above are mainly based on written sources, which are often – at least since the late Middle Ages – much more precise than archaeological material. On the other hand, written sources provide us only with a limited, if not selective fraction of the full evidence. Archaeological excavations can add significantly new information to this, particularly if supplemental material becomes available. Probably one of the best examples for this is the excavation by Sigrid von Osten (1992) of the Renaissance manor house Oberstockstall in Lower Austria. In the basement of the main building, a pit was discovered containing almost an entire inventory of an alchemists laboratory, apparently dumped there in one traumatic act. The material includes about 100 cupels, more than 300 crucibles of various types, plus abundant glass and ceramic vessels for wet chemical preparations, and various minerals and materials used in the lab. Though the full wealth of this material still needs to be explored by comprehensive scientific studies, it is already evident that it covers a good deal of the recipes given by Agricola and Ercker, contemporary to the date of deposition of the material within some twenty years (von Osten 1992). A preliminary survey of some cupels (Rehren 1997b) allowed to find out where the practice matched the recipes, and where discrepancies were obvious. Size and function of the cupels for example follow closely the system suggested by Ercker (1580), while the quality of the material used to make these cupels does not reach the high standards recommended.

Another potential of archaeological material lies in the discovery of crucibles and cupels from places and times not covered by written sources. Urban archaeology in particular can thus provide information above and beyond the documentary evidence. Nothing was known about metallurgical activity in medieval Dortmund until huge layers tremendously rich in slag and brass making crucible fragments (Rehren *et al.* 1993) were uncovered, dating from the late first millennium AD. Other finds of possible significance for early analysis (particularly cupels, predating the Renaissance by one or two centuries) are known for example from Pymont in France (Jeanjacquot 1993).

Conclusion

The 16th century knows a highly developed analytical system for mining and metallurgy, culminating in the works by Agricola and Ercker, and lasting for centuries. The information given by these sources is closely paralleled by archaeological evidence from contemporary sites, demonstrating the use of the full range of methods, tools and materials given by Agricola. This highly developed state of the art cannot possibly be the work of one generation, but most certainly owes much to earlier developments. The interpretation of documentary evidence, mostly of legal and economic character, but also archaeological finds, indicate that already during the 15th century there had been a regular use of analytical methods, integrated into the dawn of the age of rationalism. It will be a future collaborative and interdisciplinary task to further locate and characterise these early roots, by natural science, archaeological and historical means.

Acknowledgement

Much of the historical background used in this paper is owed not only to the sources as quoted in the text, but also to repeated and intensive personal communications from and discussions with Dr Christoph Bartels. His co-operative and friendly manner in sharing his ideas and unpublished results of ongoing research are highly appreciated. Any shortcomings, misinterpretations and over-simplifications are, however, entirely my own responsibility. Anna and Russel Adams improved an early version of the manuscript linguistically and are thanked for their work.

Bibliography

BARTELS Chr. 1992: *Vom frühneuzeitlichen Montangewerbe zur Bergbauindustrie – Erzbergbau im Oberharz 1635-1866*, Veröffentlichungen aus dem Deutschen Bergbau-Museum Bochum, Nr. 54, Bochum.

BARTELS Chr. 1994: Erzbergbau in Westfalen – ein Überblick, in: Chr. BARTELS, R. FELDMANN & K. OEKENTORP (Eds.), *Geologie im rheinisch-westfälischen Raum*, Münster, 35-67.

BARTELS Chr. 1996: Der Bergbau – Im Zentrum das Silber, in: U. LINDGREN (Ed.), *Europäische Technik im Mittelalter – 800 bis 1400 – Tradition und Innovation*, Berlin, 235-248.

BAYLEY J. & ECKSTEIN K. 1996: Silver Refining – Production, Recycling, Assaying, in: A. SINCLAIR *et al.* (Eds.), *Archaeological Sciences 1995*, Oxford, 113-117.

BLANCHARD I. 1984: The British Silver-Lead Industry and its Relation with the Continent 1470-1570, in: W. KROKER & E. WESTERMANN (Eds.), *Montanwirtschaft Mitteleuropas vom 12. bis 17. Jahrhundert*, Der Anschnitt, Beiheft 2, Bochum, 179-186.

ERCKER L. 1580: *Beschreibung der allervornehmsten mineralischen Erze und Bergwerksarten vom Jahre 1580*, Freiberger Forschungshefte D 34, Berlin, 1960.

HOOVER H. & HOOVER L. 1912: *Georgius Agricola De Re Metallica Translated from the first Latin edition of 1556*, London.

JEANJACQUOT J.-C. 1993: Une triple métallurgie, in: J.-C. JEANJACQUOT (Ed.), *Pymont – La forteresse oubliée*, Lons-le-Saunier, 88-98.

KING C. & NORTHOVER P. 1993: The Analyses, in: *Der Münzhort aus dem Gutshof in Neftenbach*, Zürcher Denkmalpflege, Archäologische Monographien 16, 101-117.

KRASCHEWSKI H.-J. 1990: *Quellen zum Goslarer Bleihandel in der frühen Neuzeit (1525-1625)*, Hildesheim.

LÖHNEYß G. 1617: *Bericht vom Bergwerk*, Zellerfeld.

MOLENDA D. 1984: Der polnische Bleibergbau und seine Bedeutung für den europäischen Bleimarkt vom 12. bis zum 17. Jahrhundert, in: W. KROKER & E. WESTERMANN (Eds.), *Montanwirtschaft Mitteleuropas vom 12. bis 17. Jahrhundert*, Der Anschnitt, Beiheft 2, Bochum, 187-198.

PLINIUS C. 1985: *Plinius der Ältere über Kupfer und Kupferlegierungen*, Projektgruppe Plinius (Eds.), Düsseldorf/Essen.

ODDY A. 1993: The assaying of gold by touchstone in antiquity and the medieval World, in: Chr. ELUÈRE (Eds.), *Outils et ateliers d'orfèvres des* *temps anciens*, St. Germain, 93-100.

VON OSTEN S. 1992: *Das Alchemistenlaboratorium Oberstockstall – Ein Fundkomplex des 16. Jahrhunderts aus Niederösterreich*, Dissertation Wien.

REHREN Th. 1997a: Cupel and Crucible – The Xanten process of silver recovery, *PACT* vol. 51, in press.

REHREN Th. 1997b: Kontext und Analyse der Aschkupellen von Oberstockstall, in: S. VON OSTEN, *Oberstockstall-Monographie*, in press.

REHREN Th. in preparation: *Mittelalterliche Messingproduktion in Soest.*

REHREN TH., LIETZ E., HAUPTMANN A. & DEUTMANN K. H. 1993: Schlacken und Tiegel aus dem Adlerturm in Dortmund: Zeugen einer mittelalterlichen Messingproduktion, in: H. STEUER & U. ZIMMERMANN (Eds.), *Montanarchäologie in Europa*, Sigmaringen, 303-314.

VON STROMER W. 1995: Die Saigerhüttenindustrie des Spätmittelalters. Entwicklung der Kupfer-Silber-Scheidekünste zur "ars conflatoria separantia argentum a cupro cum plumbo", *Technikgeschichte* 62, 187-219.

SUHLING L. 1976: *Der Seigerhüttenprozeß. Die Technologie des Kupferseigerns nach dem frühen metallurgischen Schrifttum.*

WEISGERBER G. & PERNICKA E. 1995: Ore mining in prehistoric Europe: An overview, in: G. MORTEANI & P. NORTHOVER (Eds.), *Prehistoric Gold in Europe – Mines, Metallurgy and Manufacture*, Dordrecht, 159-182.

WEYER J. 1992: *Graf Wolfgang von Hohenlohe und die Alchemie – Alchemistische Studien in Schloß Weikersheim 1587-1610*, Sigmaringen.

Dr. Thilo Rehren
Institut für Archäometallurgie
Deutsches Bergbau-Museum
Am Bergbaumuseum 28
44791 Bochum
Deutschland

Albrecht Jockenhövel & Christoph Willms

Archaeological Investigations to the Beginning of Blast Furnace-Technology in Central Europe

A preliminary report

The first steps of the pig iron-technology still constitute one of the great miracles in the long 3000 year-tradition of iron-making. It is not yet clear when, where and how the transition from the bloomery iron-to the pig iron-technology was made for the first time. We know, that pig iron was occasionally produced in the Ancient World and on a larger scale in Old China. However, it has still to be explored whether this knowledge was handed down through technological experience or whether it was reinvented in medieval Europe.

The early blast furnaces are rooted in the times of the bloomery-furnaces. In these small furnaces ('Rennöfen') and in the larger 'Stücköfen', iron was produced in a direct, reduced, discontinuous process as low-carbon bloom ('steel'), 'soft-' or wrought-iron. In the 'Floßöfen' and 'Hochofen' (both a specific type of blast furnaces, *i.e.* high furnaces), iron was produced in a indirect process as high-carbon, hard- or pig-iron, later as cast iron. Pig-iron had to be transformed into wrought iron by a separate process ('Frischen'), which required some additional technical installations ('Frischherde') and buildings.

Making pig-iron demands a very high temperature (more than ca. 1300° C) to smelt the iron ores with charcoal into iron. It is impossible to produce this temperature with the traditional hand- or foot-powered bellows. The new pig-iron technology is based on the use of water-power. Big wooden wheels, powered by water, moved great wooden or leather bellows, mostly a pair of bellows, which pressed the air through a hole into the smelting room of the furnace. Therefore the pig-iron industry is embedded in a major system of land-use, *i.e.* the building of mill-ponds, mill-dams, mill-races and mill-trenches.

In Central Europe water-powered mills became essential elements of the landscape from the Carolingian period onwards. The application of this system in the smelting process represents a younger development in the Middle Ages. It started some centuries later, according to some rare written records in the early 13th century AD.

It is not yet clear at which time the spread of the use of hydraulic technologies in smelting started and in which regions of Europe the oldest water-powered blast-furnaces were situated. In the earlier 1990s, only two regions were known where the invention of the indirect iron-making process could have started: the 'Märkische Sauerland', a mountainous region in the West of Germany, and the 'Norland', a region north of Uppsala in the Middle of Sweden. In the middle of 1990, a new region was added: the 'Schwäbische Alb' in southern Germany. The dating of the archaeological remains in these three regions ranges from the 11th/12th to the 15th century AD.

The present paper will report on our newest investigations in the region of the 'Märkische Sauerland', a historical iron-working landscape of Germany, the forerunner of the well-known 'Ruhrgebiet', the major region of iron-making based on the use of the coal.

The 'Märkische Sauerland' is a very mountainous region with large forests, high plateaus and deep valleys. It is an eastern part of the variscisc 'Rheinische Schiefergebirge'. In the Middle Ages, most of it was part of the 'Grafschaft Mark'. The political power of this dynasty was based mainly on the exploitation of the natural resources, especially iron and iron-making. In the region, we can distinguish two main periods of iron-making. The first one is the time of direct iron-making, the period of the 'Rennöfen' (bloomeries) from the 7th-12th/13th centuries AD. All sites were situated on the upper reaches of small rivers, near and on springs and on high plateaus. The second period – the period of the 'Massenhütten', a local name for the first blast furnaces – has to be dated to the late Middle Ages and the early Modern Age. It is characterized by the removal of the older sites of iron production to the middle and lower reaches of the rivers and the use of water-power. As a consequence, this form of iron-making – the water-powered process – was possible only in the form of the manorial system (lords of the manor, monasteries, etc.)

Based on extensive investigations in the last two decades (M. Sönnecken), an interdisciplinary project has been developed and supported by a major grant of the *Volkswagen-Stiftung Hannover*. Members of this project are the *Seminar für Ur- und Frühgeschichte* of the *Westfälische Wilhelms-Universität Münster* (Albrecht Jockenhövel), the *Westfälisches Museum für Archäologie, Amt für Bodendenkmalpflege* (Bendix Trier, Christoph Willms) and the *Max Planck-Institut für Eisenforschung Düsseldorf* (the late Dietrich Horstmann) The project is titled 'Eisen- und Stahlerzeugung im märkischen Sauerland. Eine Produktionskette von der Rennfeuerverhüttung bis zum Beginn des Osemundfrischens (ca. 800-1600 n.Chr.)'.

Our report is a preliminary review of our latest excavations of two blast-furnaces in the valley of the Kerspe river, south-west of the town of Kierspe, near Meinerzhagen/Lüdenscheid.

During the restauration of the dam on the Kerspe river, the water was let out. On the surface and at a distance of ca. 25 m from one another, two sites of iron smelting appeared. Based on geophysical measurements, it was possible to locate the remains of two furnaces and some surrounding equipment. The excavation was done in summer 1996. The investigated area covered 325 square meters. We found indeed two very well-preserved blast furnaces.

Both 'high' furnaces had been erected with their backside towards the slope. They were intact up to a height of 1.25 and 1.75 m. The main building material was loam, found on the spot. Only a few stones had been incorporated in these buildings. The outer diameter of the two furnaces is ca. 3 m. On one side of the 'high' furnace No. 1, the hole for the water-powered bellows was totally intact. Another stroke of luck was the fact that the hearth ('Gestell') of both blast furnaces was in a very good condition. Unfortunately, the front of the breast had been damaged. Therefore, we cannot say whether the breast had been 'open' or 'closed' ('Blauofen'). But in front of the furnaces, we found the hollow for the tapping of the slags and the pig-iron.

Around and underneath the furnaces, some small trenches for the drainage built of stones were situated. Beside the furnaces, we found the remains of the 'Radstube', the place of the wooden wheel, presumably an overshot wheel. The mill race was also located over a distance of some hundred metres. Above the top of the furnaces, we found the charging-plate ('Gichtplattform') from which the crushed iron ores and the charcoal were fed into the hearth. Some heavy post-holes are the remains of some wooden structures build to protect the furnaces and other working places.

Since any small finds are lacking, we cannot date this very important find place by archaeological means. The age of the two furnaces has to be dated back to the 13th century AD, based on radiocarbon-dating (Beta Analytic Inc. Miami: Beta 103851-103853).

Taking together another blast-furnace (which we partly excavated in 1995 on the river Wipper), the older excavation of 'Haus Rhade' from the 1960s, with the Jubach-Dam and the two blast-furnaces of the Kerspe-Dam, we now know five blast-furnaces dating from the 13th-16th centuries AD. Outside the 'Märkische Sauerland', only the well-known site of Lapphyttan (Middle of Sweden) gave us another preserved 'high' furnace. Unfortunately, we do not know the type of the furnace from the 'Schwäbische Alb' near Metzingen,; we have only the slags of the pig iron-process.

In the present state of research, it is too early to say that only these three regions may have had the priority of the invention and use of the pig-iron process. Unfortunately, the written records of the High and Late Middle Ages do not give any information on these subjects. However, we think new archaeological investigations have to be started in more 'innovative' regions of Europe, like Upper Italy, Burgundy or France, to find comparable sites. And we have to look at the mobility of the late medieval society which favoured the spread of new technologies in an international network of dynastic alliances, the spread of monasteries, warfare, crusades, pilgrimages, international fairs, etc. We will not exclude the possibility of an as yet unknown influence from outside of Europe, perhaps of the much older technology of Old China, transferred during the 12th/13th centuries in the course of migrations from East to West (*i.e.* the 'Golden Horde', etc).

Select Bibliography

BÖHM M. u.a., *Eisenverhüttung auf der Schwäbischen Alb*, Forschungen und Berichte zur Vor- und Frühgeschichte in Baden-Württemberg 55, Stuttgart, 1995.

HORSTMANN D., KNAU H.L. & SÖNNECKEN M., Die Roheisenerzeugung im oberen Volmetal. Ein Beitrag zur Geschichte des Eisens im Märkischen Sauerland, *Ethnogr.-Archäol. Zeitschrift* 37, 1966, 309 ff.

JOCKENHÖVEL A., Der Weg zum Hochofen - Die Zeit der spätmittelalterlichen und frühneuzeitlichen Massenhütten, in: PINSKER B. (Hrsg.), *Eisenland - Zu den Wurzeln der nassauischen Eisenindustrie* (Begleitkatalog zur Sonderausstellung der Sammlung Nassauischer Altertümer im Museum Wiesbaden 29. Januar - 23. Juli 1995), Wiesbaden, 1995, 83-98.

KNAU H.L. & SÖNNECKEN M., Fund einer spätmittelalterlichen Massenhütte in der Jubach-Talsperre, Stadt Kierspe, Märkischer Kreis. Ergebnisse einer Notgrabung, *Der Märker* 42, 1993, 223 ff.

MAGNUSSON G. (Hrsgb.), *The Importance of Iron-making. Technical Innovations and Social Change. Papers presented at the Norberg Conference on May 8-13 1995*, 2 Vols, Jernkontorets Bergshistoriska Utskott H 58 & H 62, Stockholm, 1995-1996.

Prof. Dr. Albrecht Jockenhövel
Dr. Christoph Willms
Seminar für Ur- und Frühgeschichte
Domplatz 20-22
48143 Münster
Germany

Johan Anund

The bronze industry of medieval Scandinavia – the evidence and the social position of the artisan

The lack of socio-economic studies

Thanks to the last forty years of archaeological research, many production sites and waste products have enriched our source-material related to the medieval bronze industry. This has not, however, led to a very wide-ranging knowledge of either the artisans or the role of the craftsmen in medieval society. Up to now research concerning the high and late medieval period has focused on technical topics concerning metallurgy and on chronological questions.

The archaeological evidence

Representativity

Broadly speaking, the medieval foundry sites can be divided in three categories: *sites for the production of jewellery and other small objects; cauldron-foundries* and *bell casting-pits.* The casting technique used for the production of small objects was more or less the logical sequence of an uninterrupted tradition of crafts tradition since the prehistoric period. The larger objects such as cauldrons, jugs, mortars and candlesticks, which in part required a new technology, were to a very large extent produced in separate urban foundries. The written sources allow us to make an estimate of the average number of metal-casters per town. A medium-sized medieval Swedish town would have had only one cauldron-founder (potter), one or two pewterers and a few girdlers, the latter making buckles and mounts. Considering that most towns at any point of time must have had at least one or two workshops of metal-casters, it is perhaps a little surprising that only a few sites have been identified archaeologically. In some cases, the often massive residual deposits from the workshops, fired clay, ash and charcoal, have possibly been wrongly interpreted as destruction layers and may therefore have been machined away. To the third category – that of the bell casting-pits – belong a relatively large number of excavated sites. These remains have been observed and documented partly because of their locations, although these have also led to most of the structures being badly preserved. The majority of the church bells were cast at the site of their intended use, probably for practical as well as ritual reasons. Since the bell-pits are usually situated within the churchyard or even inside the church walls, they have often been identified and interpreted correctly. Unfortunately, often only one – the mould-pit – of the two parts of the casting structures is preserved. The other part, the furnace, was built at a higher level and was as a consequence usually destroyed shortly after it had been used.

A brief compilation of excavated Scandinavian bronze-founding sites (fig. 2) follows below.

Casting of small objects

The *Helgö*-excavations yielded a vast amount of evidence including workshop structures and thousands of artefacts dated from the fifth to the eighth century (Holmqvist 1972; Arrhenius 1973a; Lamm 1977; Waller 1996). Migration period casting activities were recorded on the rural site *Gene*, as well as on several other late Iron Age sites (Rahmqvist 1983, with references). The non-permanent as well as the (semi-)permanent phases of the trading place close to *Åhus* included bronze-founding (Callmer 1991). The same is valid for the trading site at Lundeborg (Thomsen 1991). Excavations in *Ribe* have produced important information regarding Viking Age casting (Brinch Madsen 1984) as did the investigations in *Birka*. The casting waste and workshops in Birka have been dated to the eight and ninth century (Arrhenius 1973b; Jakobsson 1996). Several decades of archaeology in *Sigtuna* have resulted in a number of findings related to bronze-casting (Nordin 1993) mainly from the pre-1200 period and almost exclusively deriving from the casting of small objects. The material from *Lund* includes thirteenth-century tools and several workshop-findings: jewellery workshops (*c* 1100-1400), multi-occupational foundries (1000-

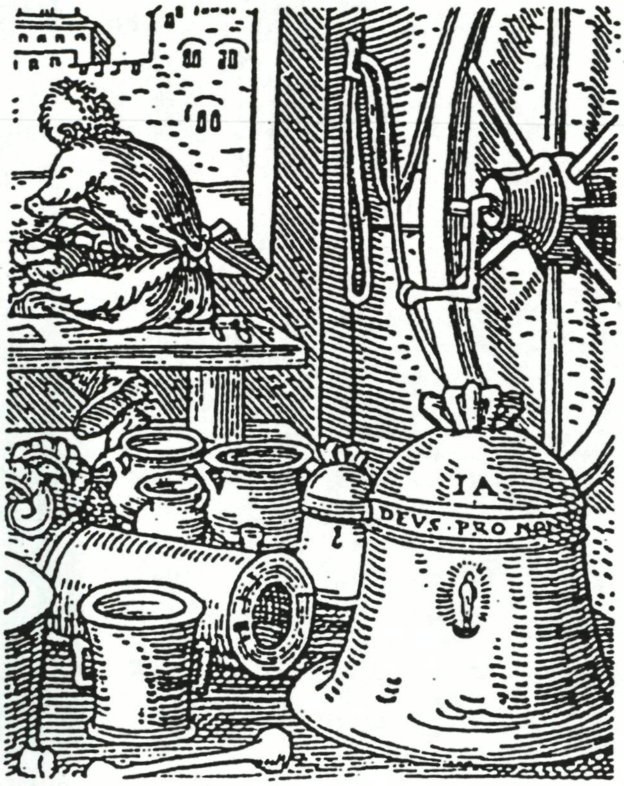


Fig. 1. - *Indoor picture of a sixteenth-century(?) bronze-foundry. The counter-window in front of the founder could be symbolic of one of the main issues of this paper – the interplay of artisans and society* (Jost Amman, *Das Ständebuch*, Insel-Bücherei nr 133, Leipzig).

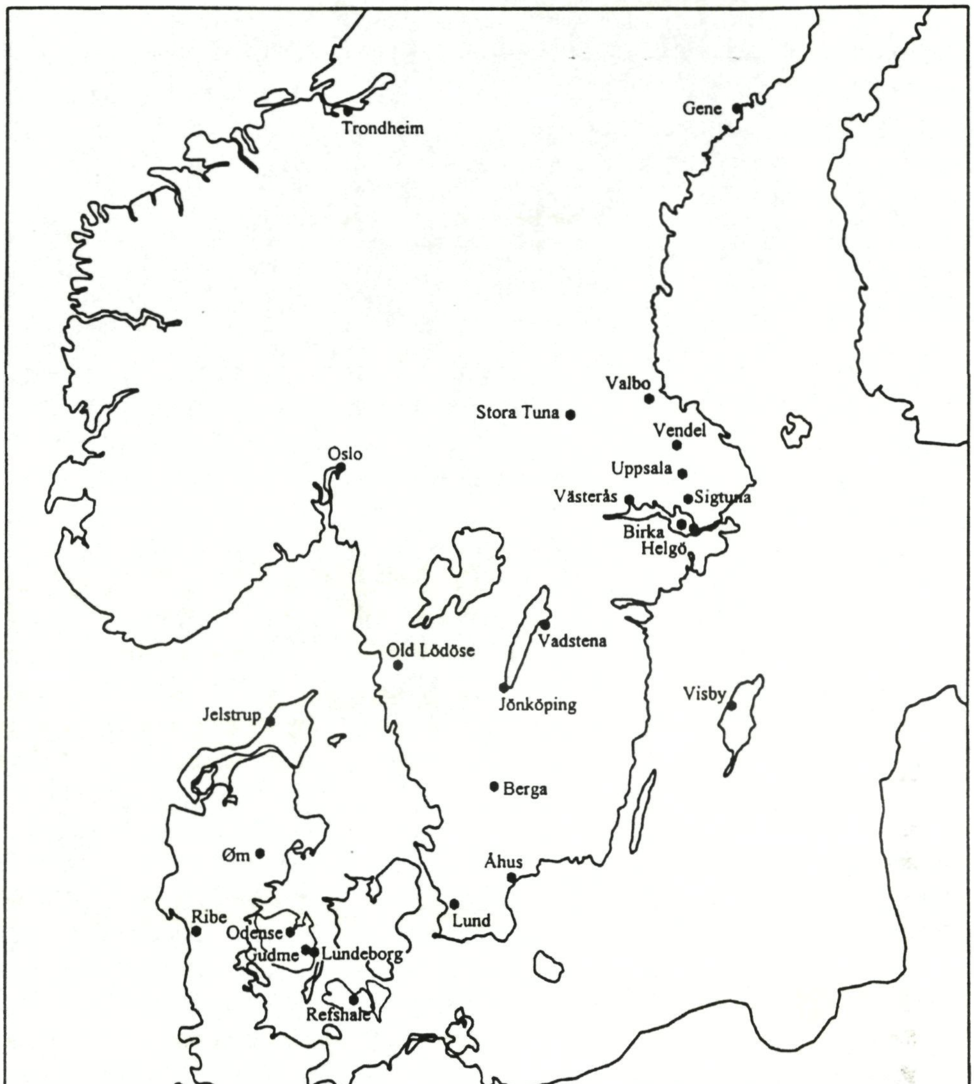
1200) and twelfth-century buckle-production (Mårtensson 1972; Bergman & Billberg 1976; 1978; Johansson 1993). *Trondheim* is also represented with a relatively large amount of material; five workshop areas dated 1025-1175 have been published (Bergquist 1989; Nordeide 1994). The extensive excavations in *Oslo* have so far only revealed little evidence for casting, dated *c* 1100-1150 (Faerden 1990; Schia 1990, 8). A non-permanent, possibly pre-urban eleventh-century workshop has been excavated in *Västerås* (Annuswer *et al.* 1990).

Unavoidably, we have to comment on the fact that almost every finding relates to production before *c* 1250. Why are later workshops for the production of jewellery, buckles, mounts and pins missing? It is true that the way of dressing changed drastically after the early medieval period and that the earlier jewellery and types of dress accessories went out of use – but new types replaced these. The demand for buckles and mounts etc. grew during the Middle Ages. Perhaps the discrepancy can be partly explained by the fact that a relatively large number of the published excavations happens to concern towns which have been established at an early date, but other factors must probably be considered too. It is also true that the Scandinavian archaeology of the 1960s and 70s focused on high medieval deposits, rather than on later strata which were often machined away. On the other hand a considerable number of more recent excavations concerning late medieval and post-medieval contexts have not changed the picture. There have to be other explanations. Did a change towards a more stationary crafts production lead to fewer and more concentrated residue deposits? During the high medieval period a category of simple jewellery, often cast with inexpensive lead-tin alloys, became increasingly common (*e.g.* Egan & Pritchard 1991). Were these objects mass-produced by casting in metal or stone moulds? If this was the case the chances of identifying workshops would be dramatically reduced since the method does not entail the same large amount of waste material as the fired clay-mould method does. This could explain why so few workshops have been located, and it would perhaps imply that inter-regional and/or international trade in this field was more important than previously believed.

Cauldron foundries

Although a wide range of objects were cast, the tripod cauldron appears to have been the main product of the high medieval urban bronze-foundries. For this reason the term *cauldron foundry* will be used for those excavated workshops specialized in the manufacturing of larger objects. In 1972, a deposit including *c* 5000 cauldron moulds was excavated in *Visby*. The site is probably the first published cauldron-foundry in Europe (Engeström 1973, 1974). The casting has been dated to the late thirteenth century. The second substantial workshop was uncovered in *Odense* in 1979. The foundry, adjacent to a Dominican friary, apparently had a production including cauldrons, church bells and other objects, and was probably run by the friary during the second half of the thirteenth century (Vellev 1983, 1988). In 1980 a multi-occupational crafts area was revealed in *Uppsala*, at the *Sandbacken* site. The bronze-working remains consist mainly of early-sixteenth-century mould deposits (Ersgård & Svedberg 1984). The best preserved cauldron foundry uncovered so far in Scandinavia is the workshop excavated in 1990 at the *Pantern* site in *Uppsala* (Anund *et al.* 1992; cf. discussion in Richards 1993, 193-198). This foundry preceded the Sandbacken workshop. The Pantern foundry is remarkable for several reasons. The structures and the artefacts were very well preserved, the grounds for dating are favorable, and we probably know the names of some of the craftsmen and own-

Fig. 2. - *Southern Scandinavia and archaeological sites mentioned in the text.*



ers of the workshop. The activities have been dated to the fourteenth and fifteenth century. Analyses have been carried out, regarding the function (Anund 1992) and the structure of the moulds. The mineralogical analysis indicates a very high standard in terms of handicraft (Hulthén 1992). This result concords with the outcome of the metallographical analysis which points out that the raw material as well as the castings rare of an almost perfect quality (Kresten & Larsson 1995; Hjärthner-Holdar & Kresten 1995).

In addition to the sites mentioned above, substantial foundry materials from several late medieval workshops have been excavated in *Jönköping* (Enbäck 1997). The archaeological evidence from *Old Lödöse* appears to have a high potential (Ekre 1980, 91) although it has not been published in detail. Related but quantitatively more limited material from *Lund*, *Västerås* (two sites), *Valbo* and *Vadstena* (two sites) should be mentioned (*Kulturen* 1986, 187; Bergquist 1991; Bergquist & Anund 1996; Tagesson, pers. comm.). The Valbo finding is interesting since Valbo is a rural site. The casting debris possibly indicates itinerant craftsmen working at an upper-class farmstead, a deanery (Broberg 1987).

Bell casting-pits

At least fourteen bell-casting sites have been excavated in Scandinavia, six in Denmark and eight in Sweden. The locations are: *Visby*, *Øm*, *Jelstrup*, *Lund* (three sites), *Berga*, *Odense* (two sites), *Refshale*, *Gudme*, *Sigtuna*, *Vendel* and *Stora Tuna* (Swanström 1977; Vellev 1977; Blomqvist 1951; Roslund 1987; Rönn 1996; Åhman 1987; Arentoft *et al.* 1985; Vellev 1988; Engberg, pers. comm.; Liebgott 1993; Bäck & Carlsson 1994; Anund 1996; Nordin & Sandberg 1996). Three of the sites might be of special interest: the early (eleventh century) construction in Lund, the Odense workshop which had a diversified production, and the unusually well preserved late medieval site in Vendel. In Vendel not only the lower section, the mould pit, was preserved but also the furnace. The furnace was a rectangular brick structure on a stone foundation (fig. 3).

Technical reconstructions

Medieval casting technique has been the subject of a considerable amount of discussion, and some of it has been based on the Scandinavian material. Lønborg's combination of theory and practice can be emphasized, together with Engeström's reconstruction of the complicated technique used for cauldron moulds. More comprehensive references regarding early medieval jewellery casting are available in Lønborg 1994. Different types of evidence for bell-casting are summarized in Vellev 1977 (Engeström 1973; Lønborg 1985, 1988, 1994; Vellev 1977, 1988; Anund 1992).

Changing organisation, changing position?

The 3rd-7th century: craftsmen of the petty kings

For several reasons, it is difficult to analyse the position of late Iron Age and early medieval artisans. The organization of crafts was probably closely linked to the organization of society. One basic question regarding the metal-workers concerns the degree of dependence. This is a matter in dispute, and some scholars emphasize the picture of craftsmen being – on the whole – rather free (Lund Hansen 1970, 93; 1975, 115; Straume 1986, 55). Others stress factors indicating a strong dependence upon the aristocracy, the chieftains and the kings (Rahmqvist 1990, 60). Andersson (1995) wants to broaden the scope of the analysis and points out that dependent as well as free metal-workers existed simultaneously. In several of the previous studies, grave material and written sources regarding blacksmiths, goldsmiths and founders are used together. The method could be dubious since these artisan groups could have had different positions in society. The crafts handling precious metals were probably closely connected to the political elite, according to the evidence from several parts of continental Europe (Näsman 1988) and Scandinavian central places of *Gudme/Lundeborg*, *Sorte Muld*, *Helgö*, *Högom*, *Bejsebakken* and *Slöinge* (Andersson 1995, 117 with references). This fact does not, however, necessarily explain the social position of the artisans.

The question of the craftsmen's position in society is probably even more difficult to answer than the separate one regarding their degree of freedom. Several researchers put forward arguments for highly respected artisans (Kjær 1900, 129; Müller-Wille 1977, 193; Arrhenius 1979, 1994, 104; Wicker 1990, 144). Arrhenius points out that the working of precious metals was linked to kings and chieftains, that the goldsmiths possibly were members of these, the ruling families of that society. Arrhenius also stresses the international contacts and influences which are strongly indicated in the results from studies of goldsmith's works (Arrhenius 1994). Rahmqvist (1990) argues that artisans of the Roman and Migration periods were at the disposal of regional petty kings and local magnates, but that the artisans nevertheless had a relatively high status and an important role as the producers of the social and political insignia in metal. In such a system, there would have existed in every petty kingdom workshops in at least two strata. A workshop situated at a site with certain central functions – though not necessarily the political or judicial central place – would have functioned as a 'school' for the regional artisans and possibly also as an innovation centre for the specifically regional object-types. The local workshops, on the other hand, would have been situated at the farms of the lower stratum of magnates (*ibid.*). Free metal workers might have had varying degrees of status depending on that of the group or individuals for whom they produced (Wicker 1990, 160; Andersson 1995, 116). This was perhaps true even in the case of unfree craftsmen. Wicker has suggested that different types of products might have led to different degrees of status for the artisan (Wicker 1994, 146).

The 8th-11th century: craftsmen during the state formation period

As compared to the research carried out regarding earlier periods, students of the Viking Age and high medieval period have rarely investigated the position of the artisan classes. One of the very few archaeological studies of the artisans' role in society is Christophersen's investigation of antler- and bone-crafts and the urbanization (1980, 1982). The general changes in society during the Viking Age (*c* 800-1050) and the early Scandinavian medieval period (*c* 1050-1200) are of vital importance for the understanding of the role of the crafts. The structures are far from clear but the period has been described as an unstable era during which increasingly important private and royal estates were being built up, which in turn created the necessary prerequisites for a kind of

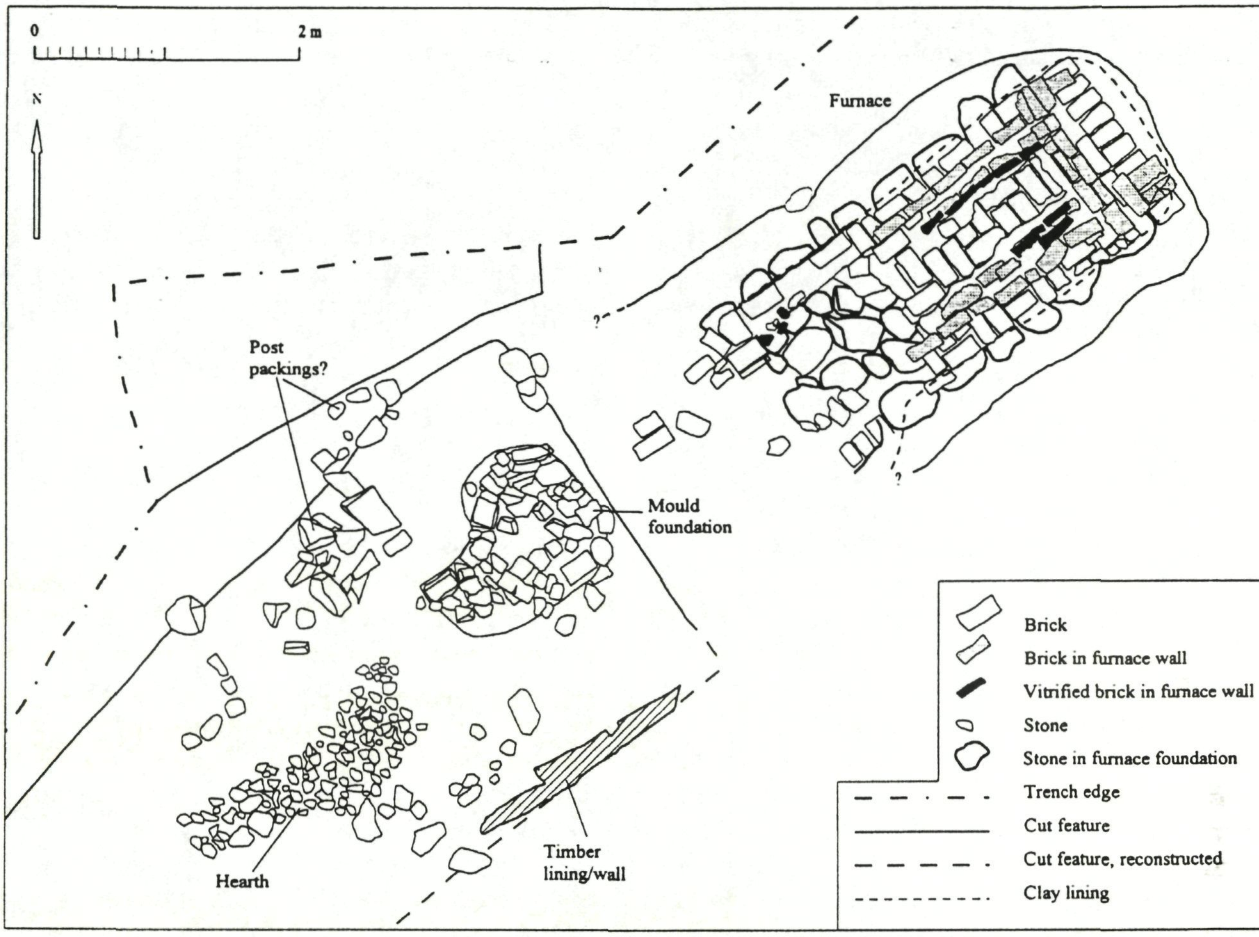


Fig. 3. - *Well-preserved late-medieval bell-casting structure in Vendel, Sweden. The site is located only thirty-five kilometres from Uppsala, and the casting was probably carried out by founders from one of the two workshops excavated in Uppsala.*

feudalism. The social and economic structures which emerged together with feudalism replaced the horizontal lines of dependence of earlier periods with vertical ties and hierarchies (*e.g.* Bloch 1978; Gurevitj 1979). The resources of the political elite in Sweden was based on external appropriation, and on control of the flow of valuables by controlling the central places (Lindkvist 1988; Svensson 1996).

The earliest towns were founded and bronze-foundries were obviously important parts of the concept of towns, as seen in the evidence from the new points-of-control in Birka, Ribe and Hedeby – and somewhat later in Sigtuna, Lund, Trondheim and Västerås. There is almost no evidence for bronze-casting in rural contexts during this period. The basic agrarian production was carried out partly by an important class of freeholders, partly by farmers who for varying reasons and in varying degrees were dependent on the magnates (Christophersen 1982a). Clean-cut lord-vassal relationships did probably exist only between the king and the members of his guard (Swedish *hird*) and between the magnates and their armed men. The growing agrarian surplus and the urge, on the part of the institutions and magnates, to control the surplus by means of taxes and land rents has been put forward as a possible indication of feudal structures in Scandinavia during the late Viking Age. The probably quite large class of freeholders was not, in Christophersen's (1982b, 134) opinion, a dynamically influencing factor in society. The artisans could have been free itinerant craftsmen producing for a more or less free market (Christophersen 1980) or, in a feudal context, occasionally or permanently contracted to the land-owning or political elite, *e.g.* the king (Brumfiel & Earle 1987; Christophersen 1989). Trade and crafts have traditionally been considered as primary factors in the urbanisation process. This opinion is often questioned and focusing on politics at the highest level reduces the artisans to a secondary phenomenon in the history of early Scandinavian towns (*e.g.* Christophersen 1982b). This, however, is a generalization and the internal socio-economic variation within the artisan group has not yet been studied

The 12th-17th century: the feudal period and the early centralistic state

Before dealing with the socio-political questions a few words about technical change in the field of bronze-working could be useful. During the beginning of this period a growing demand for large bronze objects (*e.g.* church-bells and cauldrons, led to the appearance of a new artisan class (*bell-founders, cauldron-founders, potters)*. The traditional technique used for small objects was practised by goldsmiths and girdlers. Later on, the pewterers added to the group of metal-workers producing castings. In other words – one can expect a growing social struggle within the professional group (*e.g.* Swanson 1989, 75; Egan & Pritchard 1991, ix, 18 f), as well as source-critical problems regarding the written evidence.

In Sweden, the guild system emerged at a late date, during the last decades of the fourteenth century. The known guilds are to a very large extent concentrated at Stockholm (Lindström 1991, 71). The possibilities for hypothetically earlier and more wide-spread guilds has been a matter of much dispute (Löfgren 1925; Schück 1940; Lindberg 1947; Ahnlund 1953; Lindström 1991). The earliest hints at guild-like structures in written sources are dated to the mid-fourteenth century. The organisation is described as a feudal corporate body, and not only the master craftsman but also his family, his employees and servants were connected to the guild (Lindström 1991, 229). The Scandinavian guild-system resembled the general European system in terms of feudal communities, such as social and material reproduction, internal peace, internal rules and internal judicial rights (Lindström 1991, 230). During the Middle Ages, the guilds in Stockholm and Malmö were never autonomous – the relationship to the town was regulated. The German fraternities (*Amter*) in Bergen, however, appear to have been more or less independent of the civic authorities (Lindström 1991, 231). The founding of guilds is concentrated in certain periods and according to Lindström (1991, 231), this fact does indicate that the artisans' need for support as well as the tendency of towns and kings trying to aggrandize their influence varied. The guild rules could not be changed without the participation of the town council; the town usually appointed the masters of the guilds and often had some control over the election of new members. As for judicial matters, the town had regulated rights to collect fines, but it was presupposed that the cases were settled internally within the guilds. It has been stressed that the economic and social conditions of Scandinavian guilds were to a very low degree regulated from the outside (Lindström 1991, 232).

The civic authorities in Stockholm were dominated by merchants and the limits between crafts and trade were distinctly regulated. The town also controlled the prices of the products through tariffs. Apart from these conditions the civic claims in the relation to the guilds appear to have been restricted to issues of supply, public cleansing and defence of the town, rather than dealing with economic-political control. Royal centralist guild policies did not appear until the sixteenth century. The lack of guilds in medieval Swedish towns is probably not a central issue when it comes to investigating the status of the artisans. The purpose behind the guilds might have been administrative, rather than economic (cf. Swanson 1988).

The medieval society model with its three estates presupposed that the lower class supported the upper two classes (*e.g.* Duby 1981, 179). However, merchants came to dominate parts of society in a way that in practice excluded the producing class from the concept of the system. With its system of four estates, Sweden was an exception to the rule in this respect (Watts 1987, 25). The peasantry formed the fourth class and their regulated status suggests a different and less oppressive view of the producing people, compared to the continental situation. The privileges given during the fourteenth century by the Crown to Stockholm, Malmö and Bergen, respectively, differ in character (Lindström 1991, 234) and make it clear that the centralist authority assented to, or at least accepted, different *degrees* of external regularization of the guilds in different countries. A study of the relation between the guilds and the town authority in Stockholm and in Malmö makes it clear that the hierarchic structure, as well as the subordinated position of the guilds, was more pronounced in Malmö (Lindström 1991, 234). Was the feudal element in the pre-conditions of the artisans generally less important in Sweden than it was in Denmark and the rest of Northern Europe?

During the late sixteenth century and the seventeenth century, a totally new kind of royal tactic changed the situation of the guilds and the craftsmen. An overall policy was introduced, aiming at secur-ing the interests of the Crown. During this period, there are still obvious differences between the lines of development in the Scandinavian states. In Denmark the king tried to put aside the artisans organisations, whereas the Swedish Crown forged links with the guilds and was therefore able to use them for its own purposes. The result was two types of feudal character. The Danish line of development came to be marked by conflict whereas in Sweden the mutual dependence was stressed (Lindström 1991, 237-238).

Since medieval Sweden had few guilds, relatively few towns and in some areas a relatively large measure of rural craftsmanship, it later became necessary – from the centralistic point of view – to create a system of organisations to make it possible to control and to impose taxes on the crafts. This, combined with fact that the Swedish Crown was weak during the Middle Ages (at least when compared with the situation abroad), forced the early post-medieval kings to impose an overall strategy on the crafts and on other sectors, in a way quite different from the line of development in the other Scandinavian states where the changes were less dramatic (Lindström 1991, 240). It seems as if – for different reasons – the social position of the Swedish craftsmen was comparatively good during this period of time.

Craftsmen in the urban elite?

What evidence for well-to-do – or at least well-to-do to a certain degree – bronze-founders do we find in documents and in archaeological sources? The conditions of the towns in Central Sweden appear to have been quite different from those of for instance Denmark and of certain German towns where the councils were open only to a patriarchate from the major merchants families. The social gap between artisans and merchants was narrower in the towns of Central Sweden than it was in large continental towns (Ljung 1963, 348). Stockholm was an exception in this respect. Artisans were never councillors in Stockholm during the Middle Ages (Dahlbäck 1988, 57). In the urban councils of the more important – apart from Stockholm – towns of Visby, Åbo, Kalmar, Söderköping and Lödöse craftsmen were relatively few. It is interesting, however, that in those cases when craftsmen *do* appear, the professions represented are usually those of the bronze founders, goldsmiths and tanners (Ljung 1981, 218).

Artisans had access to all levels of the civic government in medieval Västerås (Kumlien 1971, 429). In Uppsala, Enköping and Arboga, for instance, artisans frequently appear in the records as civic officials, sometimes as mayors and often as councillors or in less important positions. The records from Vimmerby show that the town rules of 1604 established that the council should be composed of one merchant, one peasant, one innkeeper and *three* craftsmen. Goldsmiths appear frequently in the higher positions. Thus, for instance, bronze-founders are recorded as mayor in Jönköping and as councillors in Uppsala. It is also plausible that in some cases even mayors and councillors without recorded artisan names actually were craftsmen. The records often omitted the title (Ljung 1981, 218).

The economic standing of bronze-founders in Stockholm is illustrated by a taxation list from 1460. Among a total of 68 groups of professionals, they belong to the 10 groups that paid the highest taxes. In this small group of better-off craftsmen we also find other metal-workers – the goldsmiths, the coppersmiths and the blacksmiths (Dahlbäck 1988, 85). Evidence from York tells about the changing prosperity of the bronze-founders (Swanson 1989, 151-158). They were doing very well during the fourteenth century, being more prosperous than most artisans. In the following century they appear to have lost much of their economic power to the pewterers. Only a few groups of Swedish artisans, such as goldsmiths, could compete financially with the merchant class (Ljung 1981). In this matter Swedish conditions were not different from those in northern Europe in general (cf. Swanson 1989, 170). In fact the social position of Swedish artisans can be compared to that of the English ones: a considerable number of the latter were perhaps not rich but made a rather comfortable living (cf. Swanson 1989, 164).

In its fifteenth-century version, the Pantern foundry mentioned earlier was a highly specialized workshop including a brick building. The archaeological results show that the site was not a dwelling place. The master of the foundry, and his relatives must have lived elsewhere. From the records we can identify probable owners of the foundry: *Olof Cauldron-founder* bought land in 1410, probably to enlarge the Pantern plot, judging from the topographical references in the records. Olof bought another plot with a different location in Uppsala – most likely his home – in 1413. Thus the master founder owned two plots and at least one brick building. The brick buildings were signs of wealth in medieval Uppsala and even as late as during the eighteenth century, there were only few of them. Another record, dated 1416, tells about *Olof Jug-caster* (pewterer). It is not clear whether he was the same person as the Olof mentioned earlier. Olof Jug-caster was a member of the gentry (Ljung 1954). If he was Olof Cauldron-founder who was a nobleman it is remarkable; if we are dealing with two different persons it is even a small sensation. Two metal-casters in the early fifteenth-century Uppsala – one of them quite well-to-do and the other one a nobleman.

It is obvious that money did not automatically buy social status. The acceptability varied within each artisan class and between crafts. The metal-working in itself was possibly connected with status. Gimpel has pointed out the high status of miners – not only were they freemen, they also had a range of special rights. This is explained as a reflection of the high regard given to the metal products (Gimpel 1992, 93-99). Heather Swanson has shown that English bronze-founders acquired considerable status. Founders became mayors in Nottingham and Leicester and there is even evidence to prove that a founder became a member of the parliament in the fourteenth century. (Swanson 1989, 75). Structurally, Swedish towns seem to have had more in common with English towns than with those in northern Germany where artisans were not allowed in the civic authorities (e.g. Dahlbäck 1987, 57). Even the neighbouring country of Denmark applied more strict rules working against the artisans in this respect. A royal Danish ordinance of 1442 proclaimed that no craftsmen should be taken into the urban judiciary (Lindberg 1947, 55).

R H Hilton has studied English and French urban culture and stresses a number of important aspects (Hilton 1995) such as the differences between smaller and larger towns. Hilton modulates general views on economy and social structures: '... *these small towns were not so structured as were the bigger urban centres. Although the borough court and borough officialdom tended to be dominated by representatives of the better-off families, there was less of a social gap between them and the rest of the borough population than one finds between the mercantile elites of the big towns and the craft producers.*'

The municipal control over the artisans could be seigniorial, royal or mercantile. In the thirteenth century relatively autonomous rule by councils with mercantile interests became common in English and French towns. Some differences are noted such as a higher degree of royal authority in England and of feudal authority through lords in France (Hilton 1995, 77). Many towns in Hilton's study had no craft organisations at all or did not get them until the late medieval period, and the craftsmen's households appear to have been multi-occupational rather than specialized (Hilton 1995, 68, 78; cf. Swanson 1988).

Conclusions

An overall conclusion from this survey is that the research regarding the early medieval Scandinavian bronze-founders has led to results which appear to be well in line with international opinions. For the later Middle Ages and the early post-medieval period, however, a divergent line of development is discernible in Sweden.

Recent investigations of smaller medieval towns in England and France make it easier to understand urban social structures in medieval Sweden than do the models presented in many earlier studies which are based on and transferred from conditions in large trading centres such as London, Lübeck and Paris. The representation of artisans in the civic authorities in Sweden has earlier been explained as caused by a lack of more suitable persons in very small towns and as an illusion – for instance, persons registered with artisan names were assumed to have inherited that name. It would probably be fruitful to discuss a more complex urban structure with in some cases rather indistinct internal boundaries. Archaeological results should be used to throw light upon specific conditions, as the written sources are deficient. The status of individual artisans and professional groups of artisans must have varied. As a consequence we must accept the thought that artisans sometimes received high civic positions in their own right.

It is obvious that research on medieval artisans must be resumed. The future investigations should try to modulate our knowledge – attention must be paid to regional differences, as well as to differences within professional and social groups.

References

AHNLUND N. 1953: *Stockholms historia före Gustav Vasa*, Monografier utgivna av Stockholms kommunalförvaltning 15.

AMBROSIANI B. & ERIKSSON B.G. 1992: *Birka. Vikingastaden*, Volym 2.

ANDERSSON K. 1995: *Romartida guldsmide i Norden III. Övriga smycken, teknisk analys och verkstadsgrupper*, Aun 21.

ANUND J. 1992: *Ett medeltida grytgjuteri i Uppsala. Olawe Grytogiwtara och andra hantverkare i medeltidsstaden*, Seminar paper, Archaeological research laboratory, Stockholm university.

ANUND J., BERGQUIST U., BÄCK M. & PETTERSSON K. 1992: A Medieval Cauldron-Foundry – Craftsmanship and Craftsmen in Pantern, in: *Rescue and Research. Reflections of Society in Sweden 700-1700 A.D.*, Riksantikvarieämbetet, Arkeologiska undersökningar, Skrifter No 2, Uppsala.

ANUND J. 1996: Medeltida bronsgjutning – teknik och hantverkare i ljuset av arkeologiska fynd, in: FORSHELL H. (ed.), *Icke-järnmetaller. Malmfyndigheter och metallurgi*, Jernkontoret H64.

ANNUSWER B., BERGQUIST U., FORENIUS S. & SYSE B. 1990: *Västerås 1000 år i centrum*, Riksantikvarieämbetet.

ARENTOFT E., BRANDT V. & GRANDT-NIELSEN F. 1985: *Albani kirke og torv*, Fynske studier XIV, Odense bys museer.

ARRHENIUS B. 1973a: East Scandinavian Salin's style I-A, *Medieval archaeology* XVII.

ARRHENIUS B. 1973b: Gjutformar och deglar påträffade i Birka, in: *Birka. Svarta jordens hamnområde*, Riksantikvarieämbetet rapport.

ARRHENIUS B. 1979: Ein Goldschmiedgrab von Hovgårdsberg, Vendel, Uppland, Schweden, *Frühmittelalterliche studien. Jahrbuch des Instituts für Frühmittelalterforschung der Universität Münster* 13.

ARRHENIUS B. 1994: Forntida guldsmedstekniker, in: KNAPE A. (ed.), *Guldets magi i saga och verklighet*, Statens historiska museum.

BERGMAN K. & BILLBERG I. 1976: Metallhantverk, in: *Uppgrävt förflutet för PK-banken i Lund. En investering i arkeologi*, Archaeologica Lundensia VII, Kulturhistoriska museet i Lund.

BERGMAN K. & BILLBERG I. 1978: *Databearbetning av metallverkstäder*, Seminar paper, Dept of Archaeology, Lund university.

BERGQUIST U. 1989: *Gjutning och smide. Metallhantverkets utveckling i Trondheim ca 1000 - ca 1350*, Meddelser fra projektet Fortiden i Trondheim bygrunn Nr 16, Folkebibliotekstomten, Riksantikvaren.

BERGQUIST U. 1991: *Kvarteren Klio och Kleopatra, Västerås*, Rapport. Riksantikvarieämbetet, UV Uppsala.

BERGQUIST U. & ANUND J. 1996: *Ett senmedeltida grytgjuteri. Domkyrkoesplanaden. Västerås*, Rapport Riksantikvarieämbetet, UV Uppsala.

BLOCH M. 1978 [1939]: *Feudal society 1. The growth of ties of dependence.*

BLOMQVIST R. 1951: *Lunds historia 1. Medeltiden.*

BRINCH MADSEN H. 1984: Metal casting. Techniques, production and workshops, in: *Ribe excavations 1970-1976*, vol 2.

BROBERG A. 1987: Vall i Valbo – en medeltida prästgård i Gästrikland, *Från Gästrikland* 1986.

BRUMFIEL E.M. & EARLE T.K. 1987: Specialization, exchange and complex societies: an introduction, *in: Specialization, exchange and complex societies. New directions in archaeology.*

BÄCK M. & CARLSSON M. 1994: *Kvarteret S.ta Gertrud 3. Stadsgårdar och gravar i Sigtuna ca 970-1100*, Riksantikvarieämbetet UV Stockholm Rapport, 60.

CALLMER J. 1982: Production Site and and Market Area. Some Notes on Fieldwork in Progress, *Meddelanden från Lunds universitets historiska museum 1981-1982,* New Series Vol. 4.

CALLMER J. 1991: Platser med anknytning till handel och hantverk i yngre järnålder. Exempel från södra Sverige, in: MORTENSEN P. & RASMUSSEN B.M. (eds), *Fra Stamme til Stat i Danmark. 2 Hövdingesamfund og Kongemakt.*

CAPELLE T. 1970: Metallschmuck und Gussformen aus Haithabu, *Berichte über die Ausgrabungen in Haithabu* 4.

CHRISTOPHERSEN A. 1980: *Håndverket i forandring. Studier i horn- og beinhåndverket utvikling i Lund ca 1000-1350*, Acta Archaeologica Lundensia 13.

CHRISTOPHERSEN A. 1982a: Drengs, Thegns, Landmen and Kings. Some Aspects on the forms of Social Relations in Viking Society during the Transition to Historic Times, *Meddelanden från Lunds universitets historiska museum 1981-1982*, New Series Vol. 4.

CHRISTOPHERSEN A. 1982b: Den urbane varuproduktionens oppkomst og betydning for den tidigmiddelalderske byutviklingen, *Bebyggelsehistorisk tidskrift* nr 3.

CHRISTOPHERSEN A. 1989: Kjøpe, selge, bytte, gi. Vareutveksling og byupkomst i Norge ca 800-1100: En modell, in: *Medeltidens födelse*, Symposier på Krapperups borg 1.

DAHLBÄCK G. 1988: *I medeltidens Stockholm*, Monografier utgivna av Stockholms stad 81.

DUBY G. 1981 [1973]: *Krigare och bönder. Den europeiska ekonomins första uppsving 600-1200.*

EGAN G. & PRITCHARD F. 1991: Dress accessories c.1150-c.1450, in: *Medieval finds from excavations in London* 3, Museum of London.

EKRE R. 1980: 3.6.2. Stadsutvecklingen, *Gamla Lödöse. Medeltidsstaden 21*, Riksantikvarieämbetet.

ENBÄCK B. 1997: Manuscript of article for: *Småländska kulturbilder 1997*, Jönköpings Länsmuseum.

ENGESTRÖM R. 1973: *En bronsgjuteriverkstad i kvarteret Priorn i Visby. Studie av dess gjutformar*, Seminar paper, Stockholm university.

ENGESTRÖM R. 1974: *Medeltida brongjuteri på Gotland. En nyupptäckt verkstad i kv Priorn i Visby*, Gotländskt arkiv.

ERSGÅRD L. & SVEDBERG V. 1985: *Sandbacken. Bebyggelse och hantverk i ett medeltida Uppsalakvarter*, Rapport Riksantikvarieämbetet UV 1984:9.

FAERDEN G. 1990: Metallgjenstander, in: SCHIA E. & MOLAUG P.B. (eds), *Dagliglivets gjenstander*, De arkeologiske utgravninger i Gamlebyen. Oslo, Bind 7, Del I, Riksantikvaren.

GIMPEL J. 1992 [1976]: *The medieval machine. The industrial revolution of the middle ages.*

GUREVITJ A.J. 1979 [1970]: *Feodalismens uppkomst i Västeuropa.*

HILTON R.H. 1995 [1992]: *English and French towns in feudal society. A comparative study*, Past and Present publications, CUP.

HJÄRTHNER-HOLDAR E. & KRESTEN P. 1995: Analyser av sulfidmalmsrelaterade malmer, slagger och metaller – en presentation av Geoarkeologiska Laboratoriets arbete i Uppsala, in: FORSHELL H. (ed)., *Icke-järnmetaller. Malmfyndigheter och metallurgi*, Jernkontoret H64.

HULTHÉN B. 1992: *Undersökning av keramiska artefakter från ett bronsgjuteri i kv Pantern i Uppsala*, Laboratoriet för keramisk forskning, Lund university.

HOLMQVIST W (ed.) 1972: *Excavations at Helgö IV. Workshop. Part 1*, Kungliga vitterhets historie och antikvitets akademin.

JAKOBSSON T. 1996: Bronsgjutarverkstäderna på Birka – en kort presentation, in: FORSHELL H. (ed.), *Icke-järnmetaller. Malmfyndigheter och metallurgi*, Jernkontoret H64.

JANSSEN W. (with contributions by DRESCHER H., RAUB C.J. & RIEDERER J.) 1987: *Eine mittelalterliche Metallgiesserei in Bonn-Schmeizrheindorf*, Beiträge zur Archäologie des Rheinlandes.

JOHANSSON C. 1993: *Söljgjutare i kv Repslagaren i Lund*, Seminar paper, Dept of archaeology, Lund university.

KJÆR H.A. 1900: Fund af smedeværktøj i grave, *Aarbøger*.

Kulturen 1986: *Årsbok för medlemmarna av Kulturhistoriska föreningen för södra Sverige*.

KRESTEN P. & LARSSON L. 1995: *Gjuterifynd från kv Pantern. Uppsala stad*, Geoarkeologi Analysrapport 4-1995, Riksantikvarieämbetet UV Uppsala, Geoarkeologiskt laboratorium.

KUMLIEN K. 1971: *Västerås till 1600-talets början*, Västerås genom tiderna, Del II.

LAMM K. 1977: Early medieval metalworking on Helgö in central Sweden, in: ODDY W.A. (ed.), *Aspects of early metallurgy*.

LIEBGOTT N.-K. 1993: Håndvaerk og teknik, in: HVASS S. & STORGAARD B. (eds), *Da klinger i muld... 25 års arkaeologi i Danmark*.

LINDBERG F. 1947 [1964, 1989]: *Hantverk och skråväsen under medeltid och äldre vasatid*.

LINDKVIST T. 1988: *Plundring, skatt och den feodala statens framväxt. Organisatoriska tendenser i Sverige under övergången från vikingatid till tidig medeltid*, Opuscula Historica Uppsaliensia 1.

LINDKVIST T. 1989: Skatter och stat i den tidiga medeltidens Sverige, *Medeltidens födelse*.

LINDSTRÖM,D. 1991: *Skrå, stad och stat. Stockholm, Malmö och Bergen ca. 1350-1622*, Acta Universitatis Upsaliensis, Studia Historica Upsaliensia 163.

LJUNG S. 1954: *Uppsala stads historia II.*

LJUNG S. 1963: *Enköpings stads historia. 1. Tiden till och med 1718.*

LJUNG S. 1981 [1961]: Hantverkare, in: *Kulturhistoriskt lexikon för nordisk medeltid från vikingatid till reformationstid* 6.

LUND HANSEN U. 1970: Kvarmløsefundet – en analyse af Sösdalastilen og dens forudsætninger, *Aarbøger 1969*.

LUND HANSEN U. 1975: Guldhåndværk i Nordens oldtid, in: SCHOU JØRGENSEN M. (ed.), *Guld fra Nordvestsjælland*.

LÖFGREN A. 1925: *Stockholm kanngjutareskrå*, Det svenska tenngjutarehantverkets historia 1:1.

LØNBORG B. 1985: Støbning af malmgryder – et rekonstruktionsforsøg, *Fynske minder 1984*.

LØNBORG B. 1988: Bronzestøbning i dansk jernalder, *Kuml 1986*.

LØNBORG B. 1994: Fremstillingen af vikingetidens skålformede fibler, *Kuml 1991-1992*.

MÜLLER-WILLE M. 1977: Der frühmittelalterliche Schmied im Spiegel skandinavischer Grabfunde, *Frühmittelalterliche studien. Jahrbuch des Instituts für Frühmittelalterforschung der Universität Münster* 11.

MÅRTENSSON A.W. 1972: *Medeltida metallhantverk i Lund*, Kulturen.

NORDEIDE S.W. 1994: Håndverket, in: *Kaupangen ved Nidelva, 1000 års byhistorie belyst gjennom de arkeologiske undersøkelsene på folkebibliotekstomten i Trondheim 1973-1985*, Riksantikvarens skrifter nr 7.

NORDIN A.-C. 1993, *Metallgjutning i Sigtuna*, Seminar paper, Dept of archaeology, Uppsala university.

NORDIN A.-C. & SANDBERG F. 1996: *Arkeologisk förundersökning. Tuna prostgård. Raä 417, Stora Tuna socken, Borlänge kommun. Dalarna*, Arkeologisk rapport 1996:13, Dalarnas museum.

NÄSMAN U. 1988: Analogislutning i nordisk jernalderarkaeologi, in: MORTENSEN P. & RASMUSSEN B.M. (eds), *Fra Stamme til Stat i Danmark. 1 Jernalderens stammesamfund*.

RAHMQVIST P.H. 1983: *Gene. On the origin, function and development of sedentary Iron Age settlement in Northern Sweden*, Archaeology and Environment 1.

RAHMQVIST P. 1990: Helgö – unikt samhällscentrum eller vanlig bondgård?, *Fornvännen* 85.

RICHARDS J.D. 1993: The Bedern foundry, in: *The medieval walled city north-east of the Ouse*, The archaeology of York 10, CBA.

ROSLUND M. 1987: Ett klockgjutningsfynd från det äldsta Lund, *Acta campanologica* vol. 2.

RÖNN V. 1996: *Stadsparken och Svanegatan i Lund*, Arkeologiska rapporter från Lund nr 16, Kulturen.

SCHIA E. & MOLAUG P.B. (eds) 1990: *Dagliglivets gjenstander*, De arkeologiske utgravninger i Gamlebyen. Oslo, Bind 7, Del I.

SCHÜCK H. 1940: *Stockholm vid 1400-talets slut*, Kungliga vitterhets historie och antikvitets akademiens handlingar 48.

STRAUME E. 1986: Smeden i jernalderen, bofast – ikke bofast, høy eller lav status?, *Universitetets oldsaksamling. Årbok 1984/1985.*

SVENSSON K. 1996: Birka i Europa, *Historiska nyheter* nr 61.

SWANSTRÖM E. 1977: Gjutplats för kyrkklocka i Visby, *Hikuin 1977.*

SWANSON H. 1988: The illusion of economic structure: craft guilds in late medieval English towns, *Past and Present* CXXI.

SWANSON H. 1989: *Medieval Artisans. An urban class in late medieval England.*

THOMSEN P.O. 1991: Lundeborg – en handelsplads gennem 600 år, in: FABECH C. & RINGTVED J. (eds), *Samfundsorganisation og regional variation. Norden i romersk jernalder og folkevandringstid.*

VELLEV J. 1977: Støbning af middelalderens kirkeklokker, *Hikuin 1977.*

VELLEV J. 1988: *Et middelalderligt bronzestøberi i Odense og noget om middelalderens klokker og gryder.*

WALLER J. 1996: *Dräktnålar och dräktskick i östra Mälardalen. Kontinuitet och förändring under folkvandringstid och vendeltid*, Aun 23.

WICKER N.L. 1990: *Migration period bracteats: art historical constructs and the archaeology of crafts production and distribution.*

WICKER N.L. 1994: The organization of crafts production and the social status of the migration period goldsmith, in: *The archaeology of Gudme and Lundeborg*, Arkaeologiske studier 10.

ÅHMAN E. 1987: En klockgjutargrop i Småland, *Populär arkeologi* 1:1987.

Personal comments

Nedanstående personer har vänligen lämnat information om opublicerade resultat.

Engberg Nils, Nationalmuseet, Köbenhavn: information om klockgjutningsanläggning i Refshale, Danmark.

Tagesson Göran, Riksantikvarieämbetet, Linköping: information om grytgjuterifynd i Vadstena, Sverige.

Johan Anund
The Central Board of National Antiquities
and Archaeological Research Loboratory
University of Stockholm
Box 137
751 04 Uppsala
Sweden

Matthijs van Nie

Early Medieval Iron Production and its Organisation in the Veluwe Area, the Netherlands

Abstract

From the early 7th to the 9th centuries AD iron production on a supra-regional scale took place in the Veluwe area, the Netherlands. The production was controlled from outside the area while the smelting itself was organised locally. The end of the production is thought to be connected to social changes and feudal influence.

Introduction

In 1990, a project started on 'The Early Historical Iron Production in the Central and Eastern Netherlands'. In the project, granted for four years by the Dutch Organisation for Scientific Research (*NWO*), an archaeologist and a geochemist/mineralogist co-operate. The main objectives are to study the technology, socio-economic conditions and impact on the environment of the iron production. The research focuses on three areas, the Veluwe, the Montferland and the Vecht area, where iron was produced on different scales using different techniques and in different periods (van Nie 1995).

The first one to draw attention to the importance of the iron production in the Veluwe area (Fig. 1) was the amateur archaeologist Moerman (Apeldoorn) who published on the subject as early as 1928 and continued to do so until his death in 1970 (Moerman 1928, 1957, 1960, 1968-9, 1970). Moerman made an inventory of the remains – slagheaps as well as open-cast mining pits – of the iron production many of which have disappeared today.

The basic needs for the production of iron are ore, wood for charcoal and clay for the building of the furnaces. In the Veluwe area, iron was produced in slagtapping furnaces, leaving characteristic tapslag and a spongy mass of iron, known as the bloom. Before the iron could be smithed, the bloom was reheated to squeeze out slag and other contaminations and to compress the metal. The process also leaves slag, known as the reheating slag. Finally objects could be smithed leaving smithing slag.

In his 'Medieval Settlement and Economy North of the Lower Rhine', Heidinga (1987a) reserved one chapter for iron production. Based on the work of Moerman (1957, 1960, 1968-9, 1970), the results of the 'Veluwe-project' (Blommesteijn *et al.* 1977) and historical sources, he concludes that large scale iron production took place in a limited area of the Veluwe during the 7th to 12th centuries AD. The limits of the production area are defined by the presence of slagheaps. The spread of slagheaps is restricted to the ice-pushed ridge of Apeldoorn roughly between

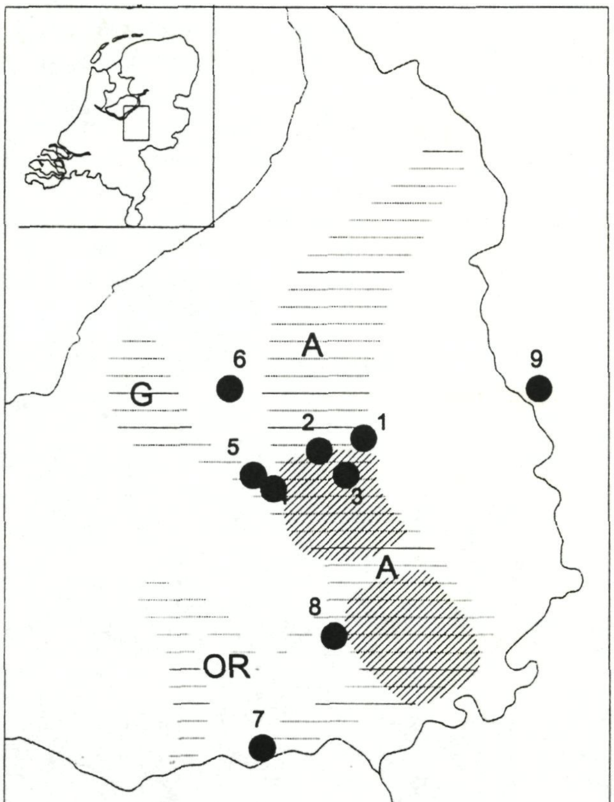


Fig. 1. - *Research area. Hatched: ice-pushed ridges; A) Apeldoorn, G) Garderen, OR) Oud Reemst. Double hatching: Ironproduction Areas. 1) Apeldoorn, 2) Asselse Veld, 3) Spelderholt, 4) Hoog Buurlo, 5) Kootwijk, 6) Huneschans, 7) Duno, 8) Deelerwoud, 9) Deventer. Scale ca 1:850,000*

Apeldoorn and the valley of the river IJssel in the south (Fig. 2).

The earliest evidence for iron production is found at Hoog Buurlo where, in the 7th century AD, blooms have been worked on a considerable scale (Heidinga 1987a). Slagheaps and mining pits are also present nearby. The youngest date is based on sherds found by Moerman in and near a few slagheaps. Written sources dating to the 9th century AD specifically mention stretches of forest without accompanying *mansiones* (*i.e.* farmsteads) in the same area as the slagheaps. In the same texts *mansiones* with the accompanying rights on the use of parts of the forests are mentioned in the Veluwe, outside the area were slagheaps occur. The forests belonged to people related to the *Reichsaristokratie*. Heidinga strongly suggests that the two (semi-)circular fortresses on the Veluwe - the Huneschans (built around 900 AD) (Heidinga 1987b) and the Duno (date unknown) - played an important part in the distribution of the iron. Both fortresses are strategically situated at traffic junctions in the north-west and south-west respectively of the iron production area. The trade in iron could have been controlled by these strongholds. The importance of the iron production is not only stressed by the number of remaining slagheaps but also by the high amount of imported ceramics in the village of Kootwijk (8-10th centuries AD) and Hoog Buurlo (7th century AD) which is comparable to that of the *port of trade* Dorestad (Heidinga 1987a). Compared to contemporaneous settlements in the well-studied Drenthe area, the village of Kootwijk is considered to be rather large (Heidinga 1987a; Waterbolk 1982). The end of the production is thought to be a result of exhaustion of wood for charcoal which also would have initiated the enormous sand-drifts on the Veluwe (Heidinga 1987a). A second cause is sought in the start of large-scale iron production in the Siegerland, the Lahn/Dill, the Westerwald and the Sauerland areas (van Nie 1990). This production started in the 10th century AD and developed fully in the 12th century AD.

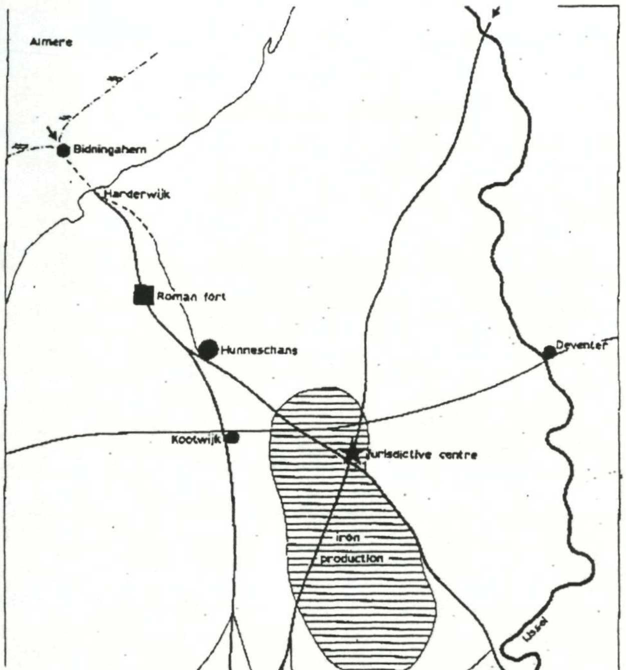


Fig. 2. - *The iron production area after* Heidinga (1987, Fig. 82).

Slagheaps and iron ore mining

The most prominent remains of the medieval iron production are the slagheaps and iron ore quarries on the ice-pushed ridge of Apeldoorn. Over 82 kilometres of mining pits and 57 slagheaps are still present or could be located. Most of them are no longer clearly visible in the landscape. Sixteen of the 37 slagheaps mentioned by Moerman (1968-9) could not, or not with certainty, be identified. Mining pits were refilled during reforestation and most of the slagheaps were removed for metalling roads and used as ore for the 19th-century blast-furnaces, for example in nearby Deventer. Both the heaps and the pits are also frequently covered by windblown-sands which makes them hard to discover. Detailed investigations show that within the area defined by Heidinga a division can be made between a northern and a southern production area (Fig. 3) (van Nie 1995). The northern area is characterised by a great density of slagheaps as well as of open-cast mining pits. The strings of pits occur generally as twins and incidentally they appear as triplets. This results from the natural occurrence of the ore. From the mining pits, a very characteristic kind of ore was quarried: the so-called *klapperstenen* (literally rattlestones), a box-stone like envelope of lepidocrocite and goethite generally around a clay core. When the core remains intact and the *klappersteen* is shaken, a rattling sound is heard. The ore was quarried in continuous trenches that nowadays appear as strings of pits with continuous banks on both sides. In all, 32 km of double strings have been mapped which gives a total length of circa 70 km including the triple parts. The 42 slagheaps in the area are generally found within 500 metres from the mining pits.

The slagheaps are more or less evenly distributed in the area. They are generally found in small groups of three or four heaps. Occasionally, like in the Spelderholt (Fig. 4), more heaps are lying close to each other. The general impression is that when more than four heaps cluster together, they are relatively small (van Nie forthcoming).

The largest remaining slagheap in the area was the subject of an extensive study (van Nie 1990). The heap turned out to consist of at least four smaller heaps partly covered with a loosely packed blanket of slag (Fig. 5). One side of the heap, adjacent to the OrderEnk (*i.e.* the arable land of Orden) also had a cover of till-soil. The heap contains 642.6 tons of slag which equals a minimum of 257 tons of iron. The production required a minimum of 694-1156.7 tons of charcoal (Joosten *et al.* 1997). The heap accounts for less than one percent of the slag once present in the whole Veluwe area (van Nie forthcoming). Only one charcoal burning site, a so-called *Grubenmeiler*, has been discovered so far but charcoal must have been burnt on an enormous scale. Extensive coppicing of oak must have taken place (van Nie forthcoming; Musch 1993). The surveys in the Spelderholt show that after the iron production, occasionally a coppice wood was cleared from stubs and brought under cultivation (see Fig. 4).

In the southern area, the spread of iron production remains is less even. Mining pits only occur in the north-eastern and south-western periphery of the area

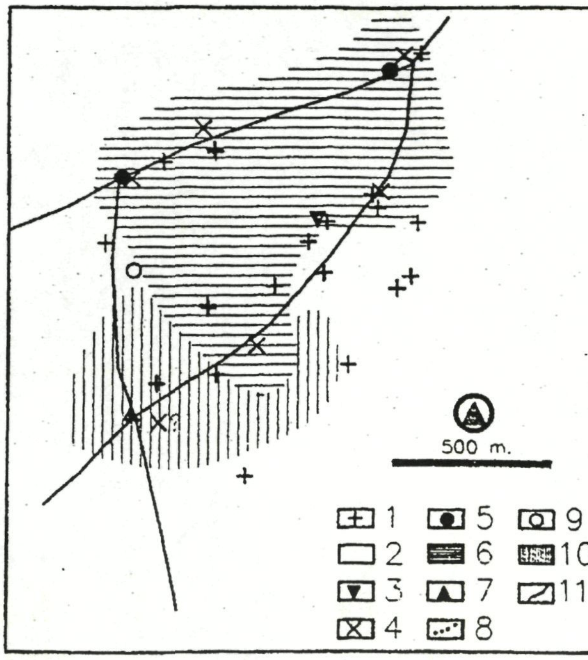


Fig. 4. - *Results of the surveys in the Spelderholt area. 1) Slagheap. 2) Blown-out sands. 3) Grubenmeiler. 4) Settlement traces. 5) Open water. 6) Arable soil. 7) Merovingian cemetery. 8) Limits of the survey. 9) In situ iron ore. 10) Old podzolic soil. 11) Reconstructed ancient roads.*

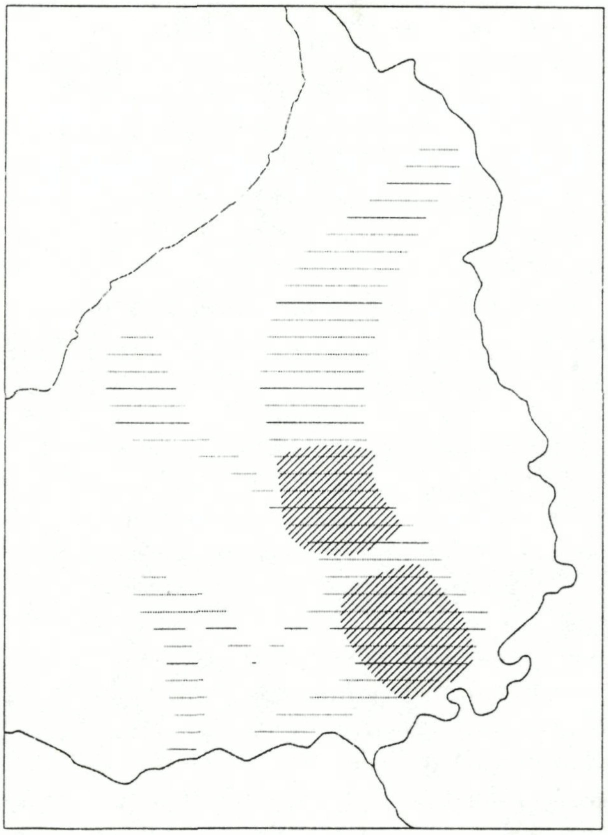


Fig. 3. - *Iron production in the Veluwe Area. See Fig. 1.*

with a total length of 12 kilometres and only as double rows; triple rows are lacking. The pits are barely recognisable because of dense vegetation and levelling during reforestation. The 15 slagheaps are more evenly spread over the area than the mining pits; distances of up to three kilometres from the nearest mining pit have been noticed five times. (van Nie forthcoming)

North versus south?

It is hard to provide an explanation for the differences between the two areas. The environmental conditions are comparable although a much larger part of the southern area borders on the valley of the river IJssel. The borderland is more hospitable for habitation than the northern area which is further away from the river valley from which it is separated by marshlands. The differences in the distribution of slagheaps and mining-pits might be explained by the differences in vegetation and availability and possibilities for prospection. In general, the southern area is more accidented than the northern one. This makes it more difficult to locate iron production remains that are covered by wind-blown sands. Especially the reconnaissance of the mining pits becomes very difficult which might account for the low number of pits compared to the northern area. The history of refor-

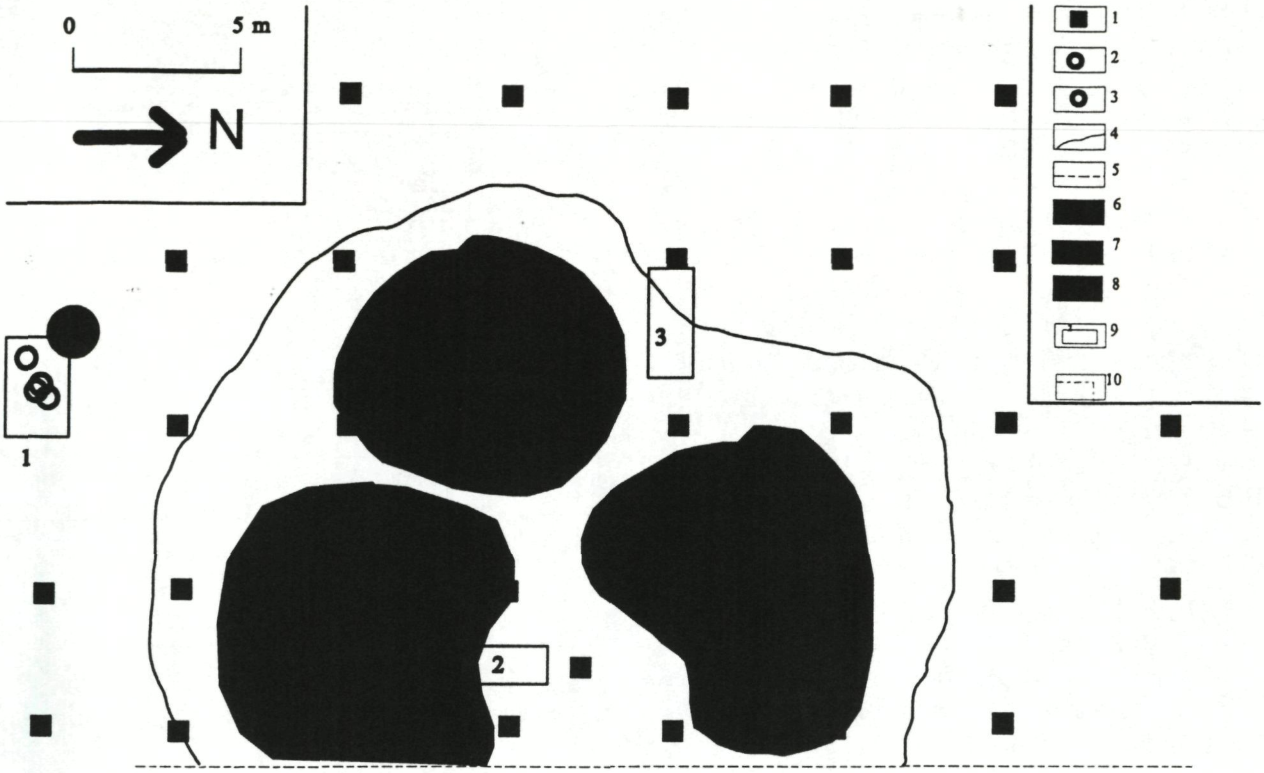


Fig. 5. - *Schematised plan of the Orderbos slagheap. 1) Shovel test. 2) Furnace. 3) Possible furnace. 4) Slag limits. 5) Fence. 6) Recent pit. 7) Concentration of slag. 8) Charcoal storage?. 9) Excavation 1988. 10) idem 1990.*

estation of the two areas is also distinct. The northern area is dominated by production forest, whereas the southern area is partly covered by a more park-like landscape. The latter is a result of the reforestation by owners of large manors and castles in the nearby valley of the river IJssel. Especially the edge of the ice-pushed ridge overseeing the IJssel-valley was reforested before attention for the iron production remains took hold. Finally it must be noted that the aforesaid Moerman, on whose observations the identification of a number of vanished remains are based, had his dwelling in Apeldoorn in the vicinity of which most of the remains are found. He probably was more familiar with the northern area than with the southern one. All of the heaps in the southern area were known to him before 1928 (Moerman 1928). In the northern area the number of known sites increased at least up to 1965 (Moerman 1968-9, 1970).

Settlements and historical sources

Early Medieval settlements are known in the Veluwe area from archaeological and historical records. Nearly all the settlements are located on the border of the ice-pushed ridges of Apeldoorn, Garderen and Oud Reemst or along (small) rivers (Figs. 6 and 7). Settlements on the ice-pushed ridge are generally located on considerably lower sites than the iron production remains. The majority of the latter are found above 45 m +NAP (NAP = Ordnance Datum) while the altitude of the settlements seldomly exceeds the 40 m isohypse. The settlement near Hoog Buurlo, at an altitude of nearly 80 m +NAP is an exception. Apart from the known settlement locations, the spread of single finds also follows this pattern. Exceptions to this are nearly always located along long distance tracks which were in use from prehistoric times onwards.

The stretches of forest mentioned in the historical texts are all located in the northern area, concentrated in the north-east (Fig. 8). Only twice a reference to stretches of forest is found for the southern area; in both cases the forests are located near the mining pits in the north-east. The latter are not, however, restricted to forest zones but also include the regular *mansiones*. (Heidinga 1987a; van Nie 1995).

The historical sources can be interpreted in two ways. On the one hand they fit in with the well-known habit of donating properties to monasteries or other ecclesiastical institutions, a practice which is common from the early Merovingian period on. On the other hand, the practice is a profitable way of disposing of properties which are no longer of primary interest. One fulfils one's religious obligations and will not have to bother about the property any longer.

The latter seems to hold true especially for outlying properties. In the process of feudalisation, widespread and fragmented landownership is no longer preferred and landowners tend to concentrate their properties in the vicinity of the court, city or stronghold where they actually reside.

North versus south?

The difference shown by the historical texts can of course be ascribed to the fact that only a very limited number of written sources survived. It is also striking that all of the references are concentrated around the so-called *Herenhul*, the jurisdictional centre of the Veluwe in late and even post-medieval times which probably has roots going further back (and perhaps even into prehistoric times). It can be assumed that especially people non-resident to the area were interested in properties nearby such a centre which will also have had some influence outside the region. One can imagine that independent authorities from outside the region arbitrated in local disputes.

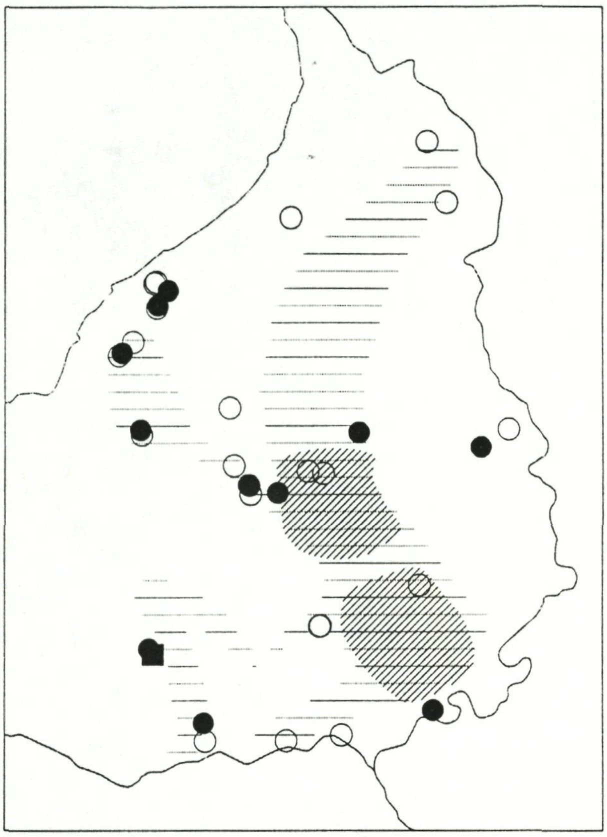
The start of the production, the Hoog Buurlo site

The first traces of iron production on the Veluwe date from the Roman Iron Age. Adjacent to settlements, remains of slagpit furnaces occur occasionally. Production took place on a household scale. (van Nie 1997).

The settlement on the Braamberg at Hoog Buurlo provides the first proof of iron production on a considerable scale on the ice-pushed ridge. The settlement, which has been excavated only in part, consists of a house, another building (possibly a shed) and two sunken huts. The sunken huts produced over 26 kgs of reheating slag and some six kilograms of bloomery iron. A partly worked bloom was excavated in a posthole(?) near the entrance of the house. The settlement is dated to the 7th century AD (Heidinga 1987a). Magnetometer research was carried out which revealed the presence of probably another sunken hut. The physical conditions were very unfavourable for detailed research (Odé & Verhagen 1992). The settlement can be interpreted as a special purpose site where blooms from smelting sites in the vicinity were worked. It functioned only for a short period, supposedly a generation, after which it was deserted as a result of sand drifts (Heidinga 1987a).

The interpretation of the Hoog Buurlo site in the perspective of the large scale production is quite difficult. One can argue for the start of the production as well as for a change in the production. Large-scale

Fig. 6. - *Archaeologically known settlements (dots) and stray finds (open circles).* (Adjusted after Blommesteijn *et al. 1977)*



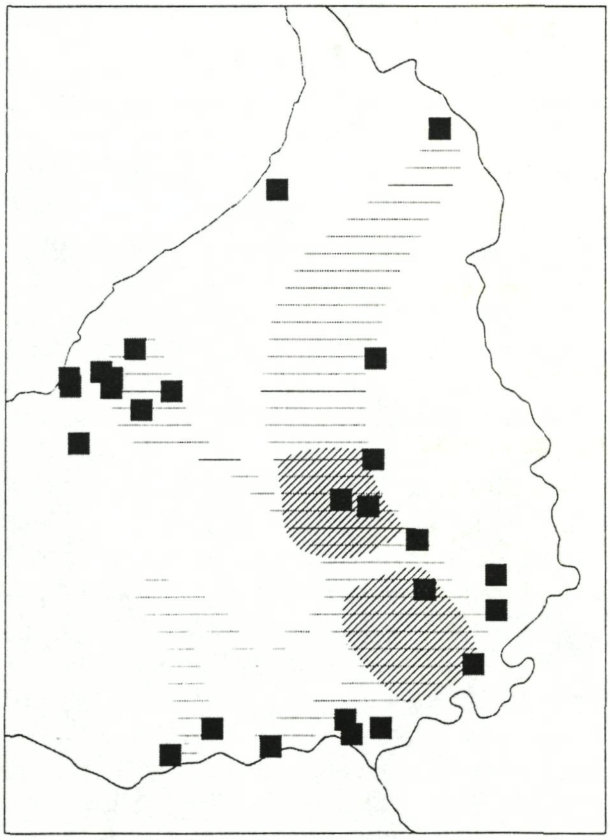
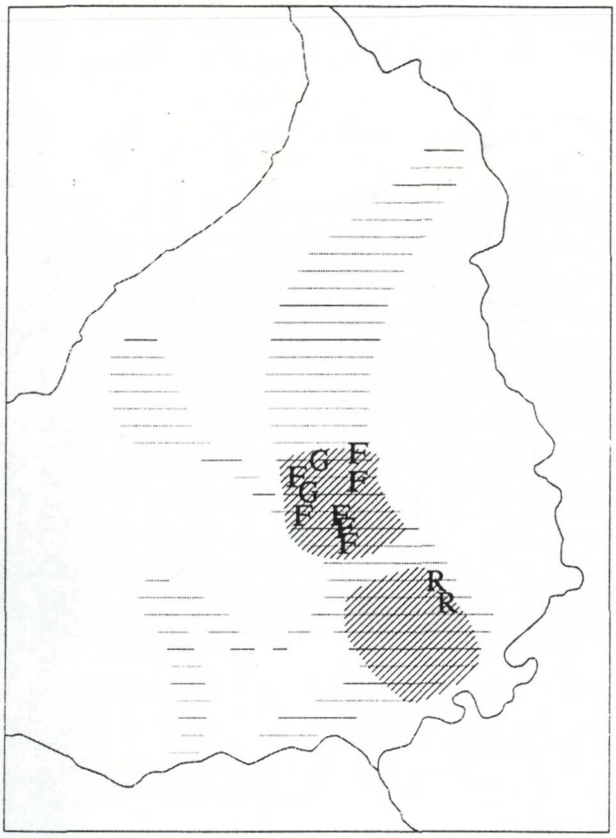


Fig. 7. - *Settlements mentioned in historical texts.* (After Blommesteijn *et al.* 1977)

Fig. 8. - *Specific forests and its owners from historic sources within the iron production area. G) Gerward. F) Folker. R) Rodgar.*



production implies some kind of organisation, which can apply to Hoog Buurlo. Likewise, one might say that after a period of exploration, the production increased and the need for a more concentrated working of the blooms was felt. Unlike the production, the working of iron is not tied spatially to the sources needed. This does not, however, agree with the short duration of the settlement. One could expect that a special purpose site would be situated on a location on which it can function as long and as efficiently as possible and would not be abandoned easily. Presumably the Hoog Buurlo site represents an early phase in the large-scale iron production. If the Hoog Buurlo site marked a change in the organisation during the production, it can be assumed that the site would have functioned longer and/or that more sites comparable to the one at Hoog Buurlo would have been discovered.

Despite extensive surveys, other settlements with the same function as Hoog Buurlo have not been found. Judging from the expected amount of reheating slag, it is highly unlikely that all of the traces that could have existed have been missed. It can be argued that the settlement traces excavated in the Deelerwoud in 1950 (Moerman 1970; Modderman 1951) belong to such a settlement. It is also situated on the border of the production area and slagheaps are nearby. Reheating slags were not, however, found or not collected. Among the finds from the excavation (collection *Gelderse Archeologische Stichting*) and in the collection Moerman (collected previous to the excavation; kept in the *Historisch Museum Apeldoorn*) only tapslag is present. Apart from a very few pieces in the excavation of the Orderbos slagheap (van Nie 1990), reheating slags are absent on the smelting sites. Probably small quantities are present but have never been recovered elsewhere; during the two excavations at the Orderbos slagheap over 18 m^3 was examined (van Nie 1990). It is quite surprising that nearly no traces of reheating activities have been found in the Veluwe area, for a substantial amount of reheating slag could be expected. Crew (1991) suggests a production to reheating slag ratio of 4:1. An amount like that cannot have been overlooked when searched for. To illustrate this, we may mention that the slagheap in the Orderbos which contains at least 642.6 tons of tapslag, would account for 160.75 tons of reheating slag.

The end of the production

As with the start of the production, it is hard to pinpoint the it's end. Most of the remains are no longer available for research or will not produce reliable data because they have been heavily disturbed. Of the majority of the datable finds, the origin and exact circumstances of recovery are no longer known or reproducible.

The youngest material associated with the slagheap has been thought to date back to the 12th century AD (Heidinga 1987a; Moerman 1956-70). The six slagheaps concerned are located in or adjacent to late medieval arable land. The sherds found in association with these heaps come from layers partly covering the heaps and which contain slags, stones and till-soil. The sherds most likely were discarded on the slagheaps while cleaning the arable land from stones, slags and stubs during ploughing. Therefore, the sherds must be of a later date than the iron production. The youngest sherds from the within the heaps themselves belong to pottery of the *Mayen* and *Badorf* types, dating from the 9th century AD.

Interpretation and reconstruction of the organisation

The scale of production indicates a certain degree of organisation. Judging from the owners of the stretches of forest in the area, influences from outside the Veluwe area could be assumed. Following Heidinga (1987a), I interpret these belongings as a way of controlling the production without being directly involved. If the production was not only controlled but also organised from outside the Veluwe, one would expect traces of such a firm grip. Heidinga proposes the ringforts Huneschans and Duno as *foci* where the iron could have been collected before leaving the area. The Huneschans, however, was constructed after the production had ceased which makes it impossible to have been of importance for the (control of) the production. The settlement at Hoog Buurlo clearly indicates influence from outside the production area for the location of the settlement makes it unlikely that it was fully self-supporting (Heidinga 1987a). The short duration of the occupation, however, makes it highly unlikely that the influence originated from outside the Veluwe, particularly because there is no evidence for more than one sites of this nature. If the abandonment of the settlement was caused only by the occurrence of sand-drifts (Heidinga 1987a), more settlements of this type would have been expected. Large-scale forestry also demands a high degree of organisation which can be supervised from the outside but which essentially requires a backup from inside the area. It must be concluded that extraction of ore, forestry, charcoal burning and smelting must be organised locally.

Calculations of the manpower needed for all of the steps in the process of producing iron are in progress. The first indications are that much more people than the 2000 accounted for by Slicher van Bath (1944) must have been present in the Veluwe area, not only to produce the iron but also to replace those involved in the iron production in their everyday tasks. Extra mouths had to be fed and less hands would have been available to produce the food that was needed. Since the bottleneck in the size and speed of production is the availability of wood, it is most likely that the iron production was not a year-round activity. The people producing the charcoal and iron were probably also involved in the most labour intensive agricultural activities such as harvesting and processing crops.

The size of the Kootwijk settlement in the Phases 2 and 3A (late 8th to mid-9th centuries AD), when up to 20 farmsteads were in use at the same time (Heidinga 1987a), might be an indication for integrated activities. When a settlement like Kootwijk only provided for the extra amounts of food and such, one would expect only an increase in storage facilities, not in complete farmsteads. A doubling in settlement size from period 1B to 2A (from 7 or 8 to 17 farmhouses) in the late 8th century AD can not be a result of normal population growth or of nucleation of settlements.

The iron production itself also had to be strictly organised in order to prevent exhaustion of the forests and to secure a steady output of iron. The most time-consuming part of iron production is the burning of the charcoal. Trees have to be felled and cut to size and the wood has to be coaled which can take up to two weeks depending on the amount of wood. This might have been - but is not necessarily - a year-round activity. Mining the ore also must have been quite labour intensive, judging from the depth (up to four metres) of some of the mining pits. The most labour intensive part of the actual production is working the bellows which can take up to 48 hours (Bielenin *et al.* 1991). The men working the bellows must be relieved regularly in order to keep the airflow stable and efficient.

Voss (1995 and pers. comm. 31-1-1997) has estimated the manpower to produce 0.5 tons of iron a year on the basis of 150-175 days per year. The Orderbos slagheap would have taken 900-1050 mandays a year (cf. Joosten *et al.* 1997). This would mean a year-round production. Since wood will no longer be available after a few years there must have been a shift in production from one location to another. The fact that the Orderbos heap consists of four or five smaller ones and that most of the slagheaps appear as groups might indicate that from time to time, the iron smelters revisited locations used earlier. Assuming a time-span for the Orderbos slagheap of 150 years, the Orderbos heap would have been revisited about every 20 years. This will give the coppice wood enough time to generate a volume of wood comparable to the trees felled originally (Oosterbaan 1988a,b). This kind of shifting cultivation also prevents too large stretches of open forest to develop. As long as the balance is not disturbed by natural causes like storms, severe droughts during longer periods or overcropping, this system is practically inexhaustible.

Most likely the northern production area can be divided into three zones in which production took place, following a shifting-cultivation-like pattern. The zones are defined by the three ore veins combined with enough forest to ensure continuous production. The zones are probably also reflected in the distribution of the properties of the two major landowners in the production area, Gerward and Folker (see Fig. 8). Within the zones, clusters of slagheaps can be recognised which will have been used one after another. The slagheaps probably were located economically near the mining sites and centrally within the area where the charcoal was burned.

The interpretation of a supposed direct relation, as proposed by Heidinga (1987a), between the production of iron and the extensive sand drifts that dominated the Veluwe in Late and Post Medieval times cannot be maintained. Small sand-drifts will have occurred during the period of production as is shown by Koster (1978). Large sand-drifts are known from the 12th century AD onwards. The continuous enlargement of the sand-drifts is of 14th century AD and later date (Lascaris 1993), centuries after the production of iron had ceased. This would have given the forest enough time to recuperate as it did between the Roman and Merovingian periods (van Geel & Groenman-van Waateringe 1987). It is reasonable to assume that the severe drought during the 10th century AD (Heidinga 1987) has hindered the natural regeneration of the forests after the production had ceased. This probably resulted in a more or less open landscape which is very favourable for sheep herding.

Conclusion

From the early 7th to 9th centuries AD, large scale iron production took place in the Veluwe area, the Netherlands. Though the production was controlled from the outside, the actual smelting most likely was organised from within the area. To cope with the demand for charcoal coppiced oakwood was used, requiring extensive forestry.

In the course of the 9th century AD, the production seems to have ceased. The few historical sources available for the area in the 9th century AD can be interpreted as diminished concern for the area and its iron. The first can be seen as a result of feudal changes, the latter also in the beginning iron production along branches of the river Rhine. The immense sand-drifts in the Veluwe area are not a direct result of deforestation for the iron production

Literature

BIELENIN K., NOSEK E. & MAZUR A. 1991: Experimental archaeology in Poland, in: *Archéologie Expérimentale 1: Le feu: métal et céramique. Actes du colloque International "Expérimentation en archéologie: bilan et perspectives", l'Archéodrome de Beaune*, Archéologie aujourd' hui, 144-148.

BLOMMESTEIJN C.M., HEIDINGA H.A., REGTEREN ALTENA H.H. VAN & VERKERK C.L. (red.) 1977: *De Veluwe. Archeologisch-historische verkenning van de bewoningsgeschiedenis tot 1200* (The Veluwe. Archaeological-historical survey into the history of habitation until 1200 AD), IPP Workingpaper 4/Historisch Seminarium werkschrift 1,. Amsterdam, 199.

CREW P. 1991: The iron and copper slags at Baratti, Populonia, Italy, *Journal of the Historical Metallurgy Society* 25/2, 109-115.

GEEL B. VAN & GROENMAN-VAN WAATERINGE W. 1987: Palynological investigations, in: GROENMAN-VAN WAATERINGE W. & VAN WIJNGAARDEN-BAKKER L.H., *Farmlife in a Carolingian Village*, Studies in Prae- and Protohistorie 1, 6-38.

HEIDINGA H.A. 1987A: *Medieval Settlement and Economy North of the Lower Rhine, Archaeology and history of Kootwijk and the Veluwe (the Netherlands)*, Assen, 243.

HEIDINGA H.A. 1987B: The Huneschans at Uddel reconsidered: some ideas about the function of a medieval ringfort in the Central Netherlands, *Château Gaillard, études de castellologie mediévale* 13, 53-62.

HEIDINGA H.A. & H.J.M. VAN NIE 1993: Oud IJzer op de Veluwe, in: BLOEMERS J.H.F., GROENMAN-VAN WAATERINGE W. & HEIDINGA H.A. (red), *Voeten in de aarde; een kennismaking met de moderne Nederlandse archeologie*, Amsterdam, 109-122.

JOOSTEN I., ELBURG M., JANSEN B. & KARS H. 1997: *Calculation of the output of an early historical iron production site in the Veluwe area, the Netherlands* (this volume).

KOSTER E.A. 1978: *De stuifzanden van de Veluwe; een physisch-geografische studie* (The sand-drifts of the Veluwe; a physical-geographical study), Amsterdam.

LASCARIS: M.A. 1993: *Stuifzand: natuur- èn cultuurlandschap. Analyse van de wisselwerking tussen menselijk handelen en natuurlijke factoren zoals die plaatsvond tijdens het ontstaan, blijven bestaan en verdwijnen van (post)middeleeuwse stuifzanden, toegespitst op het noordwesten van de Veluwe* (Drift-sands: natural and cultural landscape), unpublished MA thesis SGI/University of Amsterdam, 51

MODDERMAN P.J.R. 1951: Middeleeuwse ijzersmelterijen in het Deelerwoud, *Bijdragen en Mededelingen Gelre* 50, 13.

MOERMAN J.D. 1928: IJzerkuilen op de Veluwe, *Tijdschrift KNAG* 2e Reeks dl. XLV No. 4, juli 1928, 744-758.

MOERMAN J.D. 1957: Oude smeedijzerindustrie: ijzerkuilen en klapperstenen, *Bijdragen en Mededelingen Gelre 56*, 3-32.

MOERMAN J.D. 1960: Oude smeedijzerindustrie II: de techniek, *Bijdragen en Mededelingen Gelre* 59, 1-37.

MOERMAN J.D. 1968-9: Oude smeedijzerindustrie III: beschrijving der overblijfselen, *Bijdragen en Mededelingen Gelre* 63, 1-30.

MOERMAN J.D. 1970: Oude smeedijzerindustrie III: beschrijving der overblijfselen (vervolg), *Bijdragen en Mededelingen Gelre* 64, 1-41.

NIE M. VAN 1990: *Ertswinning en ijzerproductie op de Veluwe, aanzet tot nader onderzoek* (Ore extraction and iron production on the Veluwe: Introduction to further research), unpublished M.A. thesis, IPP/University of Amsterdam, 103.

NIE M. VAN 1995: Three Iron Production Areas in the Netherlands. Contrasts and Similarities, in: MAGNUSSON (ed.), *The Importance of Ironmaking, Papers presented at the Symposium at Norberg, May 8-13 1995*, Volume 1, Stockholm. 100-106.

NIE M. VAN 1997: Germanic Iron Provision in the Second Half of the Third Century AD. Slagpit Furnaces and Ironhoards, in: LYNGSTRØM H., L. NØRBACH & M. RASMUSSEN (eds), *Papers presented at the Nordic Iron Seminar* (provisional title).

NIE M. VAN (forthcoming): *Early Historical Iron Production in the Central and Eastern Parts of the Netherlands. An integrated archaeological - technological study: The archaeological results.*

ODÉ O. & VERHAGEN J.W.H.P. 1992: Aanvullende Archeologische Inventarisatie beheersobject Ugchelen-Hoenderloo-Varenna, *RAAP-Rapport* 60, Amsterdam.

OOSTERBAAN A. 1988a: Opbrengst tabel voor zomereik (*Quercus* robur L.) in Nederland (Yield table for Common oak (*Quercus* robur L.) in the Netherlands), *Uitvoerig verslag Band* 22-1, 31 [Proceedings of the forestry department "De Dorschkamp", Agricultural University Wageningen].

OOSTERBAAN A. 1988B: Teelt van zomer- en wintereik in Nederland (Cultivation of Common- and Durmast-oak in the Netherlands, *Nederlands Bosbouwtijdschrift* 60 (9), 287-298.

SLICHER VAN BATH B.H. 1944: *Mensch en land in de Middeleeuwen. Bijdrage tot een geschiedenis der nederzettingen in Oostelijk Nederland* (Man and Land in the Middle Ages. A contribution to the history of settlements in the Eastern Netherlands), Assen.

WATERBOLK H.T. 1982: Mobilität von Dorf, Akkerflur und Gräberfeld seit der Latènezeit. Archäologische Siedlungsforschungen auf die nordniederländiche Geest, *Offa* 39, 97-137.

Matthijs van Nie
Nieuwe Prinsengracht 130
1018 VZ Amsterdam
The Netherlands

Ineke Joosten, Marlina Elburg, Ben Jansen & Henk Kars

Calculation of the output of an early historical iron production site in the Veluwe Area, the Netherlands

Abstract

A large slagheap in the Orderbos in the Veluwe area in the Netherlands dated to the 9th century AD has been excavated and extensively studied. The ore: slag:iron ratio of the production process is calculated by the SiO_2, Al_2O_3 and MnO content of the slag and ore. The most conservative ratio is calculated to be 1.8:1:0.4 (by weight). The slagheap, which contains an estimated amount of about 642.6 tons of slag, thus would represent at least 257 tons of metallic iron. The fuel to ore during smelting is estimated by the chemistry of slag and charcoal at about 1 (by weight).

Introduction

This contribution focuses on the prospects of the chemistry of the remains of an early medieval smelting site in the Veluwe area in the Netherlands. Due to the recent development of a model which allows us to quantify the activities in terms of ore:slag:iron- and fuel to ore ratio (Joosten, Jansen & Kars 1997b), we focus on this part of the technological aspect of the NWO-project 'The technology, organisation and socio-economic conditions of early historical iron production in the central and eastern parts of the Netherlands' that started in 1990. The organisational and socio-economic part of this project will be dealt with elsewhere (Van Nie 1995). Before presenting and discussing the model an overview of the early historical iron production in the Netherlands is given:

In the Netherlands three major early historical iron production areas, encompassing sveral sites each, have been recognised (Van Nie 1995); see Fig. 1:

A) Romano Barbarian sites in the Vecht Area,

B) Sites in the Veluwe area dated from the 7th to the 10th centuries AD; and

C) Sites in the Montferland area, dated from the 9th to the 11th centuries AD.

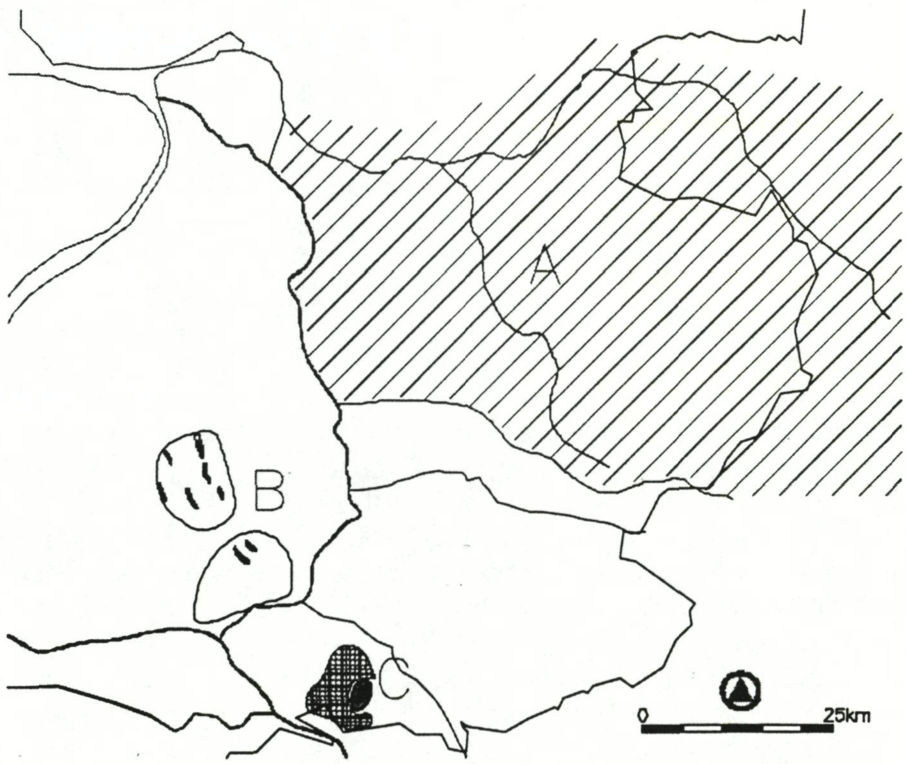


Fig. 1. - *Iron production areas in the Netherlands. Legend: hatched: slagheaps/furnaces; black: opencast mining pits; A: Vecht area; B: Veluwe area; C: Montferland area.*

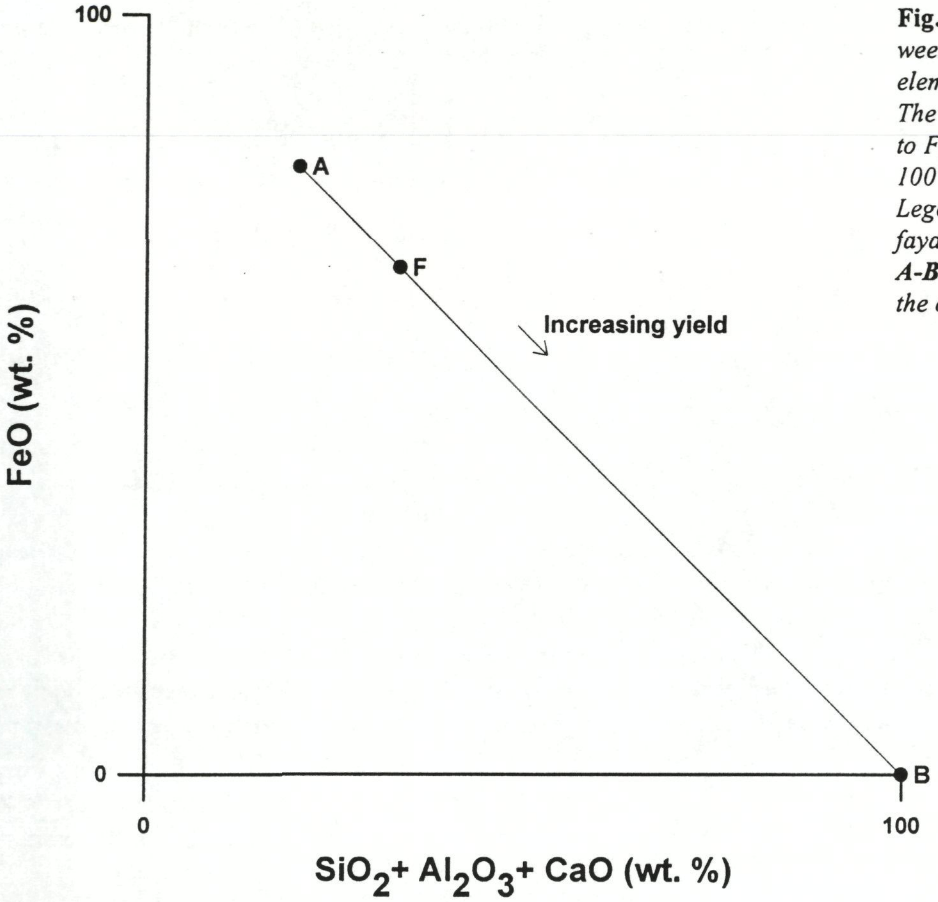


Fig. 2: *Chemical relationship between ore and slag: FeO vs. gangue elements, i.e. SiO_2, Al_2O_3 and CaO. The iron in the ore is recalculated to FeO and the total normalised to 100 wt %.*
Legend: ***A***: *ore,* ***F***: *theoretical fayalite composition (2FeO.SiO_2),* ***A-B***: *trend the slag derived from the ore will follow.*

The production areas are different in terms both in type of furnaces and application of ore type. The iron in the areas of the Veluwe and the Montferland was produced with slagtapping furnaces from rattlestones; for the production in the Vecht area bog iron ore was employed in slagpit furnaces. Bog iron ore is locally developed in streamvalleys and a certain type of iron oxide concretions, so-called rattlestones, occurs in the ice-pushed ridges in the Veluwe, Montferland and Nijmegen.

During the production process iron oxide in the iron ore has to be reduced to metallic iron and the gangue elements, mainly quartz (SiO_2), have to be separated from the iron. The reduction of iron oxide takes predominantly place by a reaction with carbon monoxide gas. This gas is generated by the incomplete combustion of carbon (charcoal). When the silica reacts with divalent iron oxide, a fayalitic melt is formed, the slag, with an approximate formula of 2FeO.SiO_2. The liquidus temperature of slag of about this composition is approximately 1175° C. When the production takes place in a slagtapping furnace the melt can be tapped and forms the tapslag. If a slagpit furnace is used, the slag can collect into a pit beneath the furnace and solidify over there forming the characteristic slagblocks. It must be noted that the early historical production process was different from the blast-furnace process in use nowadays, since iron was produced in the solid state and the slag liquefied (Tylecote *et al.* 1971). Most non-metallic chemical elements from the ore become concentrated in the slag phase, whereas some metallic elements are gathered in the iron phase. The chemical composition of the slag is – with the exception of the siderophile elements – mainly characterised by the original chemistry of the ore. Addition of special fluxes to the slag, and the contamination with fuel ash and furnace lining will complicate its chemistry; however, chemical relations in a data-set with sufficient analyses will illustrate mixture trends between the additions and slag-composition.

The reduction of iron ore can also be represented as the removal of iron (as a metal) leaving a residue of silica, alumina, lime, etc., the slag (Kresten 1987). Consider an ore with the theoretical composition A of 80 wt % FeO and 20 wt % of the gangue elements SiO_2, Al_2O_3 and CaO (Fig. 2). Reduction of the ore will yield a slag phase with a composition somewhere along A-B, and metallic iron. The position of the composition of the slag along A-B will depend on the efficiency of the production process. The closer the chemistry of the slag is to B, the more iron has been reduced to metal. The composition, however, will also be determined by the temperature in the bloomery furnace and in the order that low-melting slags might form, it would need to be in the region of fayalite (Morton & Wingrove 1969). If the slag is fayalitic its composition will be close to F (Fig. 2). It must be kept in mind that the iron in the ore will be mainly present as Fe_2O_3 and in the slag as FeO. The iron in the ore is recalculated to FeO and the total normalised to 100 wt %.

Next to the original chemistry of the ore, the composition of the slag is also determined by the efficiency of the process. To calculate the amount of ore needed to produce the slag – the ore/slag ratio (Tylecote *et al.* 1971; Bielenin & Wojda 1978; Serning 1979; Espelund 1995; Joosten *et al.* 1997b) – the chemical elements that originate exclusively from the ore must be determined. In that case a linear relationship between the elements in the ore and slag through the origin is expected when plotted in a variation diagram. The ratio is calculated by dividing the sum of the chemical elements, for example SiO_2 and Al_2O_3, of the slag by that of the ore (Equation 1). When the volatiles are also taken into account, the ratio describes the amount of ore used to produce the slags by weight.

$$\frac{\left(SiO_2 + Al_2O_3\right)_{slag}}{\left(SiO_2 + Al_2O_3\right)_{ore}} = \text{ore/slag ratio} \qquad (1)$$

The yield of the production process is defined by Tylecote *et al.* (1971) as the amount of produced iron divided by the amount of iron in the ore (Equation 2). The amount of iron in the ore is recalculated as FeO. The quantity of produced iron is calculated by the amount of FeO in the slag from the product of the ore/slag ratio and the amount of FeO in the ore.

$$\frac{\left(FeO_{ore} * ratio_{ore/slag}\right) - FeO_{slag}}{\left(FeO_{ore} * ratio_{ore/slag}\right)} = \text{yield} \qquad (2)$$

The model has been tested for the results of several experiments with reconstructions of both slagpit- and slagtapping furnaces and seems to describe the results adequately (Joosten *et al.* 1997a-b).

The aim of this study is to characterise the chemistry of the ore and slags from an early medieval smelting site in the Veluwe area. With this chemical 'fingerprint', it should be possible to certify a genetic relationship between the ore and slags; to calculate the ore:slag:iron ratio, and to establish to what extent furnace lining and fuel ash have contributed to the chemistry of the slag.

Veluwe area

On two of the ice-pushed ridges in the central parts of the Netherlands, traces of early medieval iron production are found: slag heaps and open-cast mining pits. The iron ore, so-called rattlestones, is present in certain strata in the ice-pushed ridges. Rattlestones are ellipsoidal envelopes of iron hydroxide containing a loose-fitting core of clay or silt, that make a rattling noise when shaken. The visible remains of mining activities consist of several tenths of kilometres of rows of pits from which the rattlestones have been extracted. So far the presence of over seventy slagheaps could be established in the Veluwe area. The tap slag demonstrates that furnaces with a slagtapping device were used. In 1988 and 1990 the largest slag heap of this area – situated near Apeldoorn (Orderbos) – was excavated (van Nie 1990). The smelting site was dated to the 9th century AD and provided enough material for an extensive analysis.

The following material has been collected from the Orderbos: rattlestone ore, slag (tap slag and furnace bottom, i.e. slag that has accumulated at the bottom of the smelting furnace (McDonnell 1983)), furnace lining and charcoal. Samples of rattlestone ore are also derived from open-cast mining pits situated 3350 m (the shortest distance) or 3600 m from the smelting site (Asselse Veld) on the other side of an old road, the so-called 'Hessenweg' (Van Nie pers. comm.), and some are surface finds from other parts of the Veluwe. To compare the chemistry of excavated charcoal with that of fresh ones, two pieces of birch (*Betula*) were also selected for analysis. Thin sections are made of most of the slag samples and furnace lining and studied by transmitted and reflected light microscopy.

Method

The rattlestones, slags and furnace lining were crushed in a tungsten carbide swing mill and the charcoal samples in an agate mortar. The volatile fraction (LOI) was determined by drying the samples in a furnace at 1000° C for twelve hours. This figure has been corrected for the oxidation of divalent to trivalent iron. The major elements Al, Ca, Fe, K, Mg, Mn, Na, P, Si were analysed with X-ray fluorescence (XRF). The FeO content was determined by a titration of the samples with $K_2Cr_2O_7$ in the presence of an indicator (sodium diphenylamin sulphonate). After dissolution of the samples in a mixture of 40 % HF, and 70 % $HClO_4$ and 65 % HNO_3 (2:3 parts by volume), the trace element Sr was measured with

Table 1:
Chemical composition of rattlestone ore in the Veluwe area. The total given is from the XRF, i.e. the sum of the dry oxides, with all iron as Fe_2O_3. Legend: A: magnetic pieces of burnt rattlestone from the Orderbos; B: Apeldoorn; C: smooth rattlestone from 'grindgat Klopman Ugchelen'; D: magnetic pieces of burnt rattlestone from the Spelderholt; E-G: Asselse Veld; np: not present, LOI: volatiles.

Sample	A	B	C	D	E	F	G
wt %							
SiO_2	8.1	9.9	13.9	11.1	12.0	23.9	18.3
TiO_2	0.4	0.1	0.1	0.1	0.1	0.1	0.1
Al_2O_3	2.0	3.1	2.8	3.2	2.5	2.5	2.4
FeO	np	np	np	np	np	np	np
Fe_2O_3	87.9	83.3	77.9	82.6	85.9	73.4	79.1
FeO_t	79.1	75.0	70.1	74.33	77.3	66.0	71.1
MnO	2.6	2.7	4.2	2.9	1.8	1.9	1.7
MgO	0.3	0.1	0.3	0.2	0.2	0.2	0.2
CaO	<0.2	0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Na_2O	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
K_2O	0.3	0.4	0.6	0.4	0.4	0.4	0.4
P_2O_5	0.4	0.9	0.6	0.8	0.6	0.6	0.6
Total	**102.0**	**100.3**	**100.1**	**101.1**	**103.5**	**102.9**	**102.7**
LOI	11.1	16.0	11.1	4.8	13.0	11.4	12.2
ppm							
Sr	13	10	24	16	13	15	11

Inductive Coupled Plasma Atomic Emission Spectrometry (ICP-AES). The charcoal samples were dissoluted in a mixture of 70% $HClO_4$ and 65 % HNO_3 (2:3 parts by volume) and also analysed with ICP-AES. International standards with high iron contents (FER-1 and FER-4) were analysed together with the samples to check the accuracy of the analyses. The accuracy was better than 10 % for all elements and oxides. The mineralogy of the rattlestone ore is studied by means of X-ray diffraction (XRD).

Results

The main constituent of the rattlestones is the mineral lepidocrocite, an iron hydroxide with the formula γ-FeOOH. The tap slags from the Orderbos have a homogeneous texture of acicular fayalite, few specks of metallic iron and fine-grained dendritic wüstite in a glass matrix. Fayalite in the furnace bottoms is more equidimensional in shape. The furnace bottoms often contains sand or silt. The bottom of tap slags OR5 and 6 also contains sandy material. The furnace lining consists of rounded quartz grains embedded in a clay or glass matrix. Mica, feldspar and epidote are present in trace amounts in the clay part (Elburg 1992).

The result of the chemical analysis of the ores and slags are listed in Table 1 and 2, respectively. The rattlestones contain up to 88 wt % Fe_2O_3 and quartz is the most important gangue mineral. The samples from the Asselse Veld contain on average less MnO than the other rattlestones, respectively 1.8 and 2.6 to 4.2 wt %. The slags contain 3 to 6 wt % MnO. SiO_2 and Al_2O_3 are clearly correlated from the ore to the slags and range from 8 to 25 wt % and 2 to 4.5 wt %, respectively. The furnace bottoms and two slags (OR5 and 6) are enriched in SiO_2 when compared to the ore. Calcium is present in trace amounts in the ore (up to 0.1 %), whereas most tap slags contain up to 1.3 wt % CaO.

The charcoal from the Orderbos is exclusively derived from oak, *Quercus* sp. (Musch 1991). They contain up to 10 % dry weight. This consists mainly of CaO (up to 9 wt %) or Al_2O_3 (3 wt %); see Table 4. The pieces with CaO also contain up to 500 ppm Sr. The fresh charcoal, derived from Birch (*Betula*), contains 0.45 to 0.75 wt % dry weight and this consists mainly of CaO, K_2O and MgO, respectively, up to 0.21, 0.27 and 0.15 wt %. The amount of Sr is below the detection limit.

Table 2:
Chemical composition of slags and furnace lining from the Orderbos. The total given is from the XRF, i.e. the sum of the dry oxides, with all iron as Fe_2O_3. Legend: OR4-6, OR8-9, OR21-25: tap slag; OR10, OR33, OR39: furnace bottom; OR12: furnace lining.

Sample	OR4	OR5	OR6	OR8	OR9	OR21	OR22	OR24	OR25	OR10	OR33	OR39	OR12
wt %													
SiO_2	19.3	24.8	16.8	18.2	22.6	12.3	18.0	15.7	14.0	31.2	16.3	25.1	78.4
TiO_2	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.3	0.2	0.2	0.6
Al_2O_3	4.4	4.5	3.4	4.6	5.3	3.8	4.1	3.8	3.7	5.9	3.1	3.8	8.0
FeO	57.8	51.0	56.6	53.8	47.7	64.3	56.2	62.7	60.6	39.0	58.6	57.7	1.7
Fe_2O_3	5.5	6.5	12.3	10.2	10.4	9.0	6.2	4.6	8.1	10.7	12.4	3.4	5.3
FeO_t	62.7	56.8	67.7	62.9	57.1	72.3	61.8	66.8	67.9	48.6	69.0	60.8	6.4
MnO	5.7	4.4	4.2	5.5	6.0	4.8	6.7	4.9	5.2	5.6	4.2	3.0	0.1
MgO	0.5	0.4	0.3	0.4	0.5	0.3	0.4	0.4	0.4	0.5	0.4	0.4	0.6
CaO	1.3	0.9	0.4	0.8	1.0	0.2	1.0	0.7	0.8	1.0	0.5	0.4	0.2
Na_2O	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.4
K_2O	0.9	0.9	0.3	0.4	1.2	0.7	1.3	1.0	1.0	1.0	0.3	0.7	1.7
P_2O_5	0.8	0.8	0.8	0.8	0.8	0.7	0.9	0.8	0.8	0.7	0.7	0.6	0.1
Total	**102.8**	**100.1**	**101.6**	**101**	**101**	**103.1**	**101.2**	**101.7**	**101.4**	**100.2**	**103.2**	**101.7**	**97.3**
LOI	-0.5	0.5	0.3	0.7	0.2	0.7	1.1	0.6	0.5	0.3	1.3	1.2	0.9
ppm													
Sr	36	40	20	26	43	44	104	80	82	45	42	40	53

Ore/slag ratio and yield

The percentage of iron present in the slags from the Orderbos is still quite high (Fig. 3), as could be expected from the mineralogical composition of the main component (fayalite contains 70 wt % FeO). The iron content of the rattlestones is only somewhat higher than that of the slag. This means that careful selection of the most iron-rich pieces of ore was necessary to have any iron oxide left over for the reduction to metallic iron. Traces of selection and ore dressing, a thin layer of crushed rattlestones mostly with gravel and coarse sand adhering and cores of rattlestones, have been found adjacent to one of the mining pits excavated in 1988 (van Nie 1990).

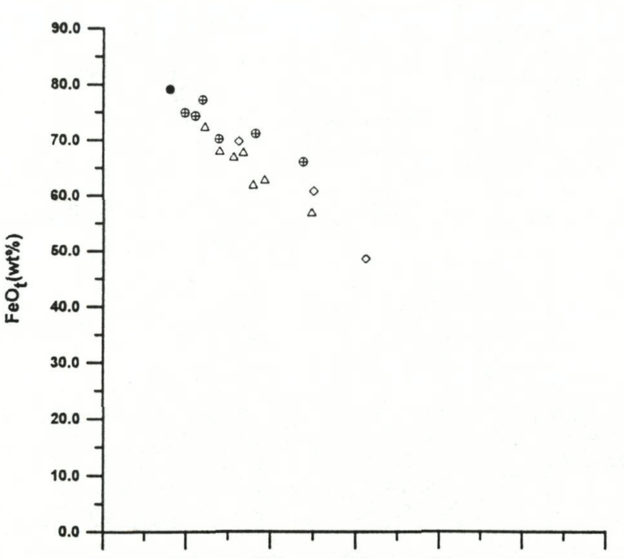


Fig. 3. - *Chemical relationship between ore and slags from the Orderbos: FeO_t vs. SiO_2.*

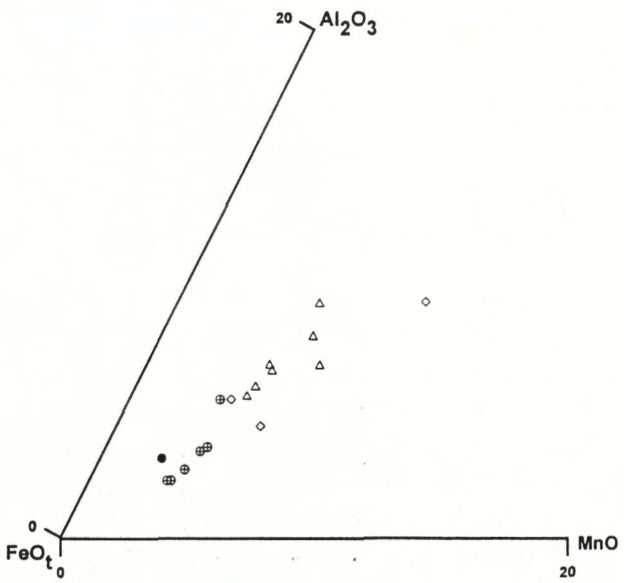


Fig. 4. - *Triangular variation diagram of FeO_t, Al_2O_3 and MnO. Legend: **filled circle**: rattlestone A found in the slag heap of the Orderbos; **cross in circle**: rattlestones B to G, **triangles**: tap slags; **diamonds**: furnace bottoms*

The oxides FeO_t, Al_2O_3 and MnO have been normalised and plotted in a triangle diagram in figure 4. Both Al_2O_3 and MnO enter the slag phase, whereas FeO_t enters the slag as well as the metallic iron. Therefore, related slags and ore should plot on one line originating from the FeO_t-corner, with the ores plotting nearest to the corner. The rattlestones and the slags approximately plot on the same line in the right order.

The ores and slags show a linear relationship between Al_2O_3 and SiO_2 through the origin (Fig. 5A). Tap slag OR5 and 6 and the furnace bottoms are enriched in SiO_2, most probably due to adhering sand. Also MnO is positively correlated with both Al_2O_3 and SiO_2 (Fig. 5B). The three samples of rattlestone ore from the Asselse Veld contain on average too little MnO to be related with the Orderbos slags (Fig. 5B). Rattlestone A, found in the slag heap at the Orderbos, seems to be the most promising candidate for a representative ore analysis because of its high FeO_t content and ratio of gangue elements that is comparable to those of the slags (black dot in Fig. 3, 4 and 5A, B).

The slags are enriched in CaO compared to the ore (Fig. 6). The elements Mg, K and P also do not show a relationship from the ore to the slags through the origin. Therefore only SiO_2, Al_2O_3 and MnO can be used to calculate the ore/slag ratio.

Taking a rather average slag analysis like OR25 we get an ore:slag:iron ratio of 2:1:0.6 (by weight); see Table 3. The loss of weight during smelting is caused by both the volatile content of the ore and the difference in weight between Fe^0 and Fe_2O_3. The yield of the process is calculated to be 52 %. When other slags are used in this calculation (both lower and higher in FeO_t), we get an idea of the variations possible in the yield: 44 to 68 % (Table 3). This agrees with the figure of 30 to 50 % which was calculated by Tylecote (1971). Other literature values for the ratios are 1:0.3-0.5 for slag:iron (Serning 1979), 2:1:0.3 for ore:slag:iron (Bielenin & Woyda 1978, Bielenin 1995) and 1.4:1:0.3 also for ore:slag:iron (Voss 1995).

The slag heap in the Orderbos consists of several (at least 4) densely packed smaller heaps and looser packed material covering the sides and rim of the heap. The total calculated volume of the dense material is 277.6 m^3 and that of the less dense packed material 55 m^3. The packing factors for loose and dense areas of the heap are determined by weighing the amount of roughly washed slag from a known volume of sample and dividing this by the average specific gravity of the slags which was determined as 3.5. The packing factors are 0.6 for the dense and 0.34 for the loose packed material. The minimum amount of slag in the heap in the Orderbos is estimated to be about 642.6 tons. (van Nie 1990) The most conservative estimation of the amount of iron produced is made by using the ore:slag:iron ratio for OR21: 1.8:1:0.4. In that case, it is concluded that the slagheap represents at least 257 tons of metallic iron. The smelting site has proven to be in use during (part of) the 9th century AD; presumably, it dates from the early 8th to the second half of the 9th centuries AD (Van Nie, pers. comm.).

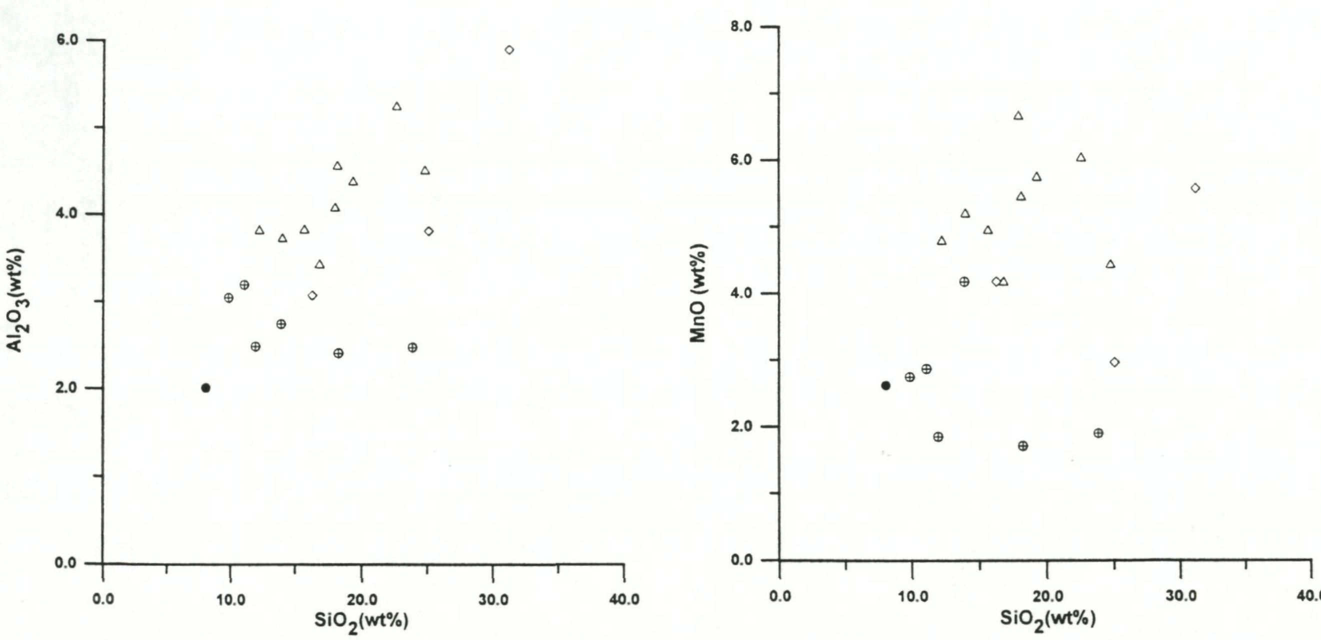


Fig. 5A and B. - *Chemical relationship between ore and slags from the Orderbos: Al_2O_3 and MnO vs. SiO_2. Legend: **filled circle**: rattlestones A; **cross in circle**: rattlestones B to G, **triangles**: tap slags; **diamonds**: furnace bottoms.*

Table 3.
Calculated figures. Legend as in Table 1 and 2. The fuel/ore ratio is calculated with the fresh charcoal (h-j in Table 4).

Slag	FeO_t (wt %)	Ore	FeO_t (wt %)	Ore:Slag:Iron	Yield (%)	Fuel/ore ratio
OR25	67.9	A	79.1	2.0:1:0.6	52	1.7-2.8
OR5	56.8	A	79.1	2.5:1:1.0	68	1.6-2.6
OR21	**72.3**	**A**	**79.1**	**1.8:1:0.4**	**44**	**0.6-1.0**
OR39	60.8	A	79.1	2.0:1:0.6	58	0.8-1.3

For comparison purposes, the output of the Orderbos smelting site is set next to that of other sites. It must be noted that only figures from smelting sites have been taken into account and not the output of whole regions. Sunnanäng, the largest excavated smelting site in the Dalarna region (Sweden), dating from the 9th to the 11th century AD, yielded 21 tons of iron produced in slag tapping furnaces (Serning 1979). The calculations are based on the iron content of related ore and slag and also take into account the influence of the charcoal on the slag composition. During the 2th to 7th centuries AD, a calculated amount of 150 tons of iron, based on the iron content of the roasted ore and slag, has been produced in slagpit furnaces in Snorup, Denmark (Voss 1995). The iron production from the 3 hectare complex of the Bardown site in the Weald (Britain), dating from 120 to 240 AD, yielded a calculated amount of 4,500 tons of iron (Cleere 1976). The weight of the slag, 13,500 tons, is calculated by estimating the packing factor and specific gravity of the slag as 0.5 and 3, respectively. The iron production was arrived at using a slag to metal ratio of 1:0.3 based on figures of Bielenin (1974). So far it seems that the large scale of the iron production in the Orderbos was unique for the period in western Europe. The discussion about the destination of such large amounts of iron is beyond the scope of this study and will be presented elsewhere.

Fuel to ore ratio

Calcium oxide is present in trace amounts in the ore (up to 0.1 wt %), whereas the tap slags contain up to 1.3 wt %. In the triangle diagram with Al_2O_3, MnO and CaO (Fig. 6), related ore and slags should plot in the same area (all three oxides enter the slag phase) unless any of the oxides have been added to the slag from another source, as furnace lining or fuel ash.

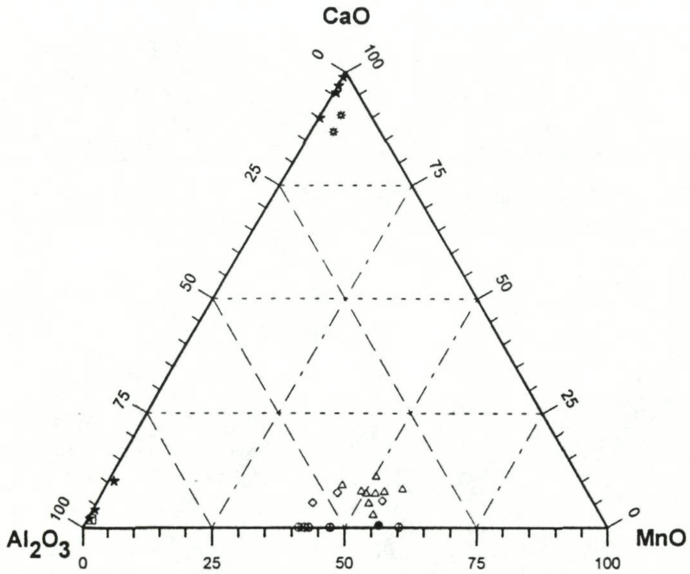


Fig. 6. - *Triangular variation diagram of Al_2O_3, MnO and CaO.*

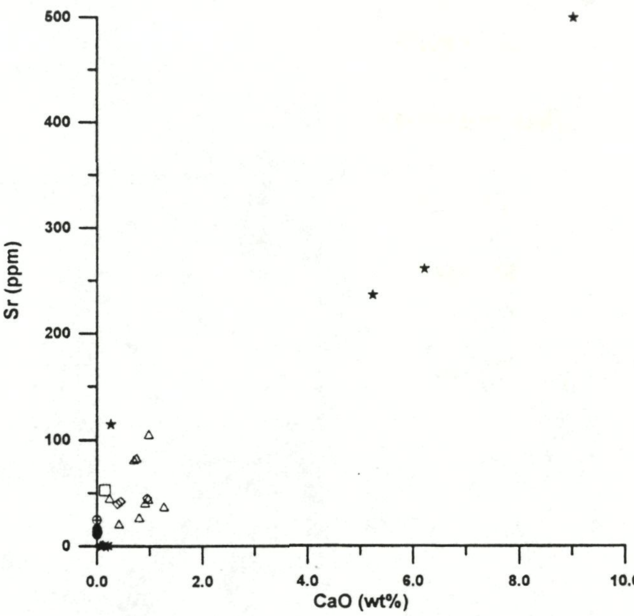


Fig. 7. - *Chemical relationship between ore and slags from the Orderbos: Sr vs. CaO.*
Legend: ***filled circles****: rattlestone ore A;* ***cross in circle****: rattlestone ore (B to G);* ***triangles****: tap slags; diamonds:*

Table 4: *Chemical composition of charcoal. Legend:* ***a-g****: early medieval charcoal from Oak (Quercus) from the Orderbos;* ***h-j****: fresh charcoal from Birch (Betula),* ***k****: Oakwood ash from Lower Saxony (Hartmann 1994),* ***NA****: Not Analysed.*

Sample	a	b	c	d	e	f	g	h	j	k
wt %										
SiO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.90
TiO_2	0.01	<0.001	<0.001	<0.001	0.01	0.01	<0.001	<0.001	<0.001	0.11
Al_2O_3	0.69	3.23	0.10	0.22	2.47	2.28	0.17	0.02	0.01	0.30
FeO	0.31	0.07	0.05	0.16	0.29	0.26	0.10	0.01	<0.001	0.69
MnO	0.01	0.01	<0.001	0.02	0.01	0.03	0.01	0.01	0.01	3.53
MgO	0.62	<0.001	0.44	0.25	<0.001	<0.001	0.53	0.15	0.07	5.40
CaO	6.22	0.07	9.05	5.23	0.10	0.26	5.86	0.21	0.13	43.1
Na_2O	0.03	0.01	0.04	0.02	0.03	0.02	0.04	0.01	<0.001	0.49
K_2O	0.13	0.02	0.15	0.07	0.04	0.06	0.09	0.27	0.18	29.6
P_2O_5	0.02	<0.001	0.01	<0.001	0.01	<0.001	0.01	0.06	0.05	11.40
Total	**8.04**	**3.43**	**9.84**	**5.97**	**2.96**	**2.92**	**6.64**	**0.73**	**0.45**	**98.60**
ppm										
Sr	262	<0.03	499	237	<0.03	115	377	<0.03	<0.03	1069

The slags are displaced from the rattlestone onwards to the CaO corner. This cannot result from contamination with the furnace lining, as it plots in the Al_2O_3 corner. The CaO presumably originates from the charcoal, which can contain up to 9 wt % of CaO (Table 4). There is also a strong correlation between Sr and CaO in the slags from the ore to the charcoal (Fig. 7). The presence of Sr in the pieces of fresh charcoal could not be detected, but the ashes which are much more concentrated might contain some as illustrated by the analyses of oakwood ash (Quercus) by Hartmann (1994) which contains 1069 ppm of Sr (sample k in Table 4).

The contribution of the charcoal to the chemistry of the slag is reflected by its enrichment in calcium with respect to the ore. The ore/slag ratio can be used to calculate the surplus CaO in the slag (Equation 3).

$$\left(CaO_{slag} \,/\, ratio_{ore/slag}\right) - CaO_{ore} \qquad (3)$$

The fuel to ore ratio is estimated by dividing the surplus of CaO in the slag by the amount of CaO in the charcoal. The chemistry of the excavated pieces of charcoal, however, might have been altered during their stay in the soil since it is well known for its adsorbence qualities. Small particles of clay could have been adhering to the surface of the charcoal, despite extensive cleaning by ultrasonic vibration, also contributing to the dry weight. The pieces of fresh charcoal contain more than ten times less dry weight and may reflect the original chemical composition of the used charcoal somewhat better. Therefore, the CaO-content of the fresh charcoal – 0.13 and 0.21 wt % respectively – is used to calculate the fuel to ore ratio. The ratio ranges from 0.6 to 2.8:1 (by weight); see Table 3. Since the exact amount of CaO in the used charcoal is not known, this can only be a rough estimation. Presumably only the charcoal which is in close contact with the slag can be resorbed, therefore the calculated amount of charcoal will represent the fuel to ore ratio during smelting. The amount of charcoal used to pre- and after-heat the furnace is not included in the figure. Calculated figures from an experiment with a slagpit furnace range from 0.7 to 1.2 which agrees well with the ratio as charged, i.e. 1:1 (Joosten *et al.* 1997b). An experiment with a slagtapping furnace yielded a calculated ratio ranging from 0.8 to 1.5:1 which was a little lower than the ratio as charged, i.e. 1.5:1 (Joosten *et al.* 1997a). The most conservative fuel to ore ratio during smelting, estimated by the slag with the lowest ore:slag ratio: OR21, ranges from 0.6 to 1:1 (by weight). It can be concluded that the slagheap of the Orderbos represents the consumption of at least 694 to 1156.7 tons of charcoal.

The amount of charcoal that could be produced per hectare of coppice forest can be estimated to be 10 ton +/- 50 % per hectare (Voss 1995). The estimation is partly based upon accounts written around 1800 for the blast furnace in Port-Brillet, France; they got 12 tons of charcoal from each hectare of coppiced oakwood. Accordingly, the iron production in the Orderbos would have consumed at least 69.4 to 115.7 hectares of coppice wood.

Conclusions

The output and charcoal consumption of an early medieval smelting site in the Orderbos in the Veluwe area have been calculated by the chemistry of related slags and ore, and charcoal. The most conservative ore:slag:iron ratio is 1.8:1:0.4 (by weight). Therefore the slagheap in the Orderbos, containing an estimated minimum amount of 642.6 tons of slag, represents at least 257 tons of metallic iron. The fuel to ore ratio during smelting was roughly estimated to range from 0.6 to 1.0 (by weight). The iron production would in that case have consumed at least 694 to 1156.7 tons of charcoal. The proposed figures represent minimum amounts based upon the most conservative ratio's.

Acknowledgements

Grateful thanks are expressed to: R. de Man (ROB, Amersfoort) and the late Ms. van Hoorn-van Berkel, (IPP, Amsterdam) for the determination of charcoal; and to drs. M. van Nie for the inspiring discussions. The project was granted by the Dutch Organisation for Scientific Research (NWO).

Literature

BIELENIN K. 1974: *Starozytne Górnictwo i Hutnictwo Zelaza w Górach Swietokrzyskich.* Warsaw, Cracow.

BIELENIN K. 1995: Frühgeschichtliches Eisenhüttenwesen im Heilig-Kreuz-Gebirge (Góry Swietokrzyskie) und seine Beziehungen zu Nowoklinowo in der Transkarpatischen Ukraine, *Študijné Zvesti Archeologického Ústavu sav* 31, 89-98.

BIELENIN K. & S. WOYDA 1978: Zwei Eisenherstellungszentren des Altertums im Weichselbogen (1.Jh. v. u. Z.- 4. Jh. u.Z.), *Eisen + Archäologie,* Bochum, 25-55.

CLEERE H. 1976: Some operating parameters for Roman ironworks, *Bulletin of the Institute of Archaeology* 13, 233-46.

ELBURG M.A. 1992: *The technology of early ironproduction in the central and eastern parts of The Netherlands*, Amersfoort/Utrecht (Internal Report).

ESPELUND A. 1995: *Iron Production in Norway during Two Millennia. From the ancient bloomery to the early use of electric power,* Trondheim.

HARTMANN G. 1994: *Chemie der Erde* 54, 103-28.

JOOSTEN I. & M. VAN NIE, 1996. Introducing the Early Iron Production in the Netherlands, in: *Early Iron, Netvaerk for tidlig jernteknologi* 1, p. 29-42.

JOOSTEN I., M. VAN NIE & P. DE RIJK 1997a: Experiment with a slagtapping furnace at the Historisk Arkæologisk Forsøgscenter, Lejre, in: H. LYNGSTRØM, L. NØRBACH & M. RASMUSSEN (eds), *Proceedings of the Nordic Iron Seminar* (provisional title).

JOOSTEN I., B. JANSEN & H. KARS 1997b: The use of a model to describe bloomery production in the Netherlands, in: H. LYNGSTRØM, L. NØRBACH & M. RASMUSSEN (eds), *Proceedings of the Nordic Iron Seminar* (provisional title).

KRESTEN P. 1987: The ore-slag-technology link: Examples from bloomery and blast furnace sites in Dalarna, Sweden, in: SCOTT B.G. & H. CLEERE (eds), *The crafts of the blacksmith*, 29-33.

MCDONNELL G. 1983: Tap slags and hearth bottoms, or, how to identify slags, *Current Archaeology* 86, 81-83.

MORTON G.R. & J. WINGROVE 1969: Constitution of bloomery slags: part 1: Roman, *Journal of the Iron and Steel Institute* 210, 1556-1564.

MUSCH J. 1991: *Houtskool van de Veluwe: een onderzoek naar de economische exploitatie van de natuurlijke rijkdommen van de "woestijn" van Nederland in de Middeleeuwen* [Charcoal from the Veluwe: an investigation of the economical exploitation of the natural resources of the "desert" of the Netherlands in the Middle Ages], unpublished B.A. thesis, University of Amsterdam.

NIE M. VAN 1990: *IJzerkuilen en slakkenhopen op de Veluwe, aanzet tot nader onderzoek* [Ore extraction and Iron production on the Veluwe. Introduction to further research], unpublished MA thesis, University of Amsterdam.

NIE M. VAN 1995: Three Iron-producing Areas in the Netherlands: Contrasts and Similarities, in: G. MAGNUSSON (ed), *The Importance of Ironmaking. Technical Innovation and Social Change, papers presented at the Norberg Conference on May 8-13 1995,* vol. 1, 100-106.

SERNING I. 1979: Prehistoric Iron Production, in: H. CLARKE, *Iron and Man in Prehistoric Sweden*, Stockholm, 50-89.

TYLECOTE R.F., J.N. AUSTEN & A.E. WRAITH 1971: The Mechanisms of the Bloomery Process in Shaft Furnaces, *Journal of the Iron and Steel Institute* 209, 342-363.

VOSS O. 1995: Snorup - An Iron producing Settlement in West Jutland, 1st- 7th Century AD, in: G. MAGNUSSON (ed), *The Importance of Ironmaking. Technical Innovation and Social Change,* papers presented at the Norberg Conference on May 8-13 1995, vol. 1, 132-139.

Ineke Joosten, Marlina Elburg,
Ben Jansen & Henk Kars
State Service for Archaeological Investigations
(ROB)
Kerkstraat 1
3811 CV Amersfoort
The Netherlands

Caroline Tulp

Early Medieval Metal-working at the *Terp* Tjitsma (Frisia, The Netherlands)

The *terp*[1] Tjitsma is situated near Wijnaldum in the north of the Netherlands (fig. 1). It was excavated from 1991 until 1993. The excavation was carried out under direction of J.C. Besteman, J.M. Bos and H.A. Heidinga (University of Amsterdam and State University of Groningen).

The *terp* Tjitsma is only one of a whole series of *terpen* near Wijnaldum. Because of a shortage of funding, it has not been excavated completely. This was the first time a part of a Dutch *terp* has been excavated so systematically. Even the smallest pieces of metal were retrieved by the use of metal-detectors and the contents of features were sieved to retrieve finds as small as seeds and beads.

One of the reasons for the excavation was the great amount of metal objects that were discovered by amateur-archaeologists with metal-detectors. The finds made it clear that the top part of the *terp* had been eroded and what was left of the features and finds needed to be studied. At the same time an excavation could also give more information about the erosion of this type of monument.

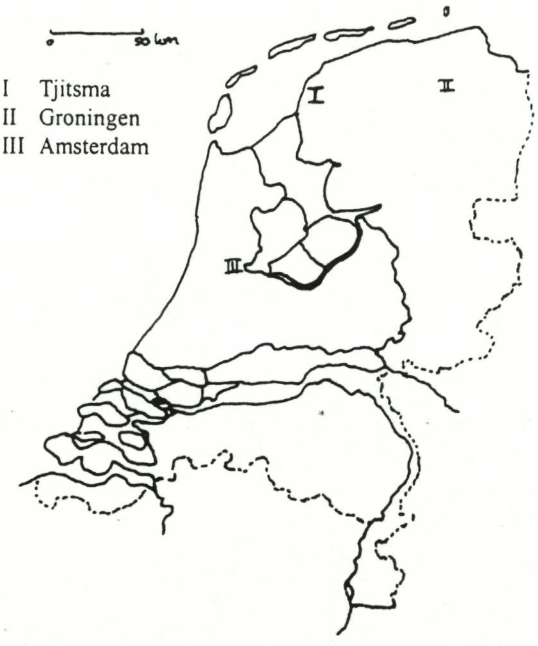


Fig. 1. - *Map of the Netherlands with the location of the terp Tjitsma (from:* Besteman & Bos & Heidinga 1993, 10).

During the excavation it became clear that many different craftsmen have worked at the *terp*. Traces have been found of glass-blowing, deerhorn- and bone-working, amber-working, sewing, weaving, spinning, and metal-working. The present paper is about the metal-working that took place at the *terp* between the 2nd and the 10th century AD. The majority of finds related to metal-working are the iron-slags and the hearth-material. Other categories are fragments of crucibles, moulds, scrap metal, touchstones, semi-manufactured objects and ingots.

Evidence for Metal-working

Gold-working

The evidence for gold- and silver-working was not discovered in the same amount as traces of copper-working or iron-working. Small pieces of waste metal and failed castings were not easily discarded, but remelted and then made into new objects. Another reason is that gold and silver were not as often used as the other metals.

There are no gold ingots known from the *terp*. Gold was probably obtained in the form of objects and then remelted. It is a fact that gold was melted at Tjitsma: two golddrops and a fragment of a crucible with tiny drops of gold were found. The crucible fragment is dated 650-750 AD and was found in the vicinity of two fragments of goldwire from the same period. The goldwire consisted of a thin, flat strip of gold that was twisted into a round wire. These wire fragments could be used for filigrain-work[2]. One of the two golddops cannot be dated, because it was

[1] A *terp* is a man-made mound in the Dutch coastal area. It protected the people living on it from the sea.

[2] Andersson (1995, 125) calls this type 'strip-twisted'. The wire can not only be used for filigrain-work, but can also be used as decoration on clothes as is the case in a Frankish cemetery (Janssen 1991, 78). The wire-fragments at Tjitsma, however, do not have a grave-context.

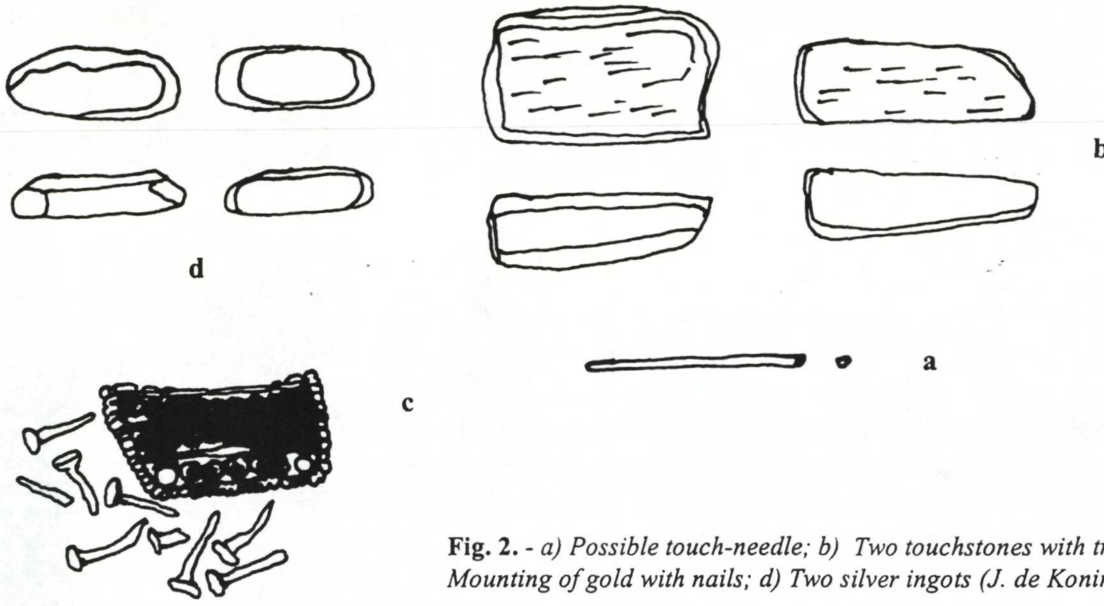


Fig. 2. - *a) Possible touch-needle; b) Two touchstones with traces of gold; c) Mounting of gold with nails; d) Two silver ingots (J. de Koning).*

found on the surface. The other is dated 850-950 AD and was in a context with two silverdrops and an golden object that could be a touch-needle (fig. 2, a).

Two touchstones (fig. 2, b) were discovered during the excavation. One is black and rectangular and has traces of gold on two sides. It was found in a layer of sods and is dated 550-650. The second stone has a smaller width and has traces of gold on one side. The stone is grey/blue and is not as smooth as the other one. This touchstone came out of a well (which has been dated to the 9th century AD). A decorated gold mount (fig. 2, c) is one of the nicer finds. It is folded and had a secondary use of holding a few golden nails. It is not known whether the mounting was made locally or elsewhere.

During the excavation, a few thin gold pieces were found that turned out to be parts of the golden brooch (with almandine) that had already been discovered in 1954. The precise context of the brooch is unknown. The brooch has been analysed and among the scratches on the back are some cutting marks. It has been suggested that the brooch was in the possession of a goldsmith so it could be repaired[3].

Three years after the excavation, a matrix of copper was found among some scrap copper-fragments. This type of matrix was used to provide a sheet of gold with a waffle pattern (such sheet-gold was used as a background beneath the almandine and made it shinier and brighter). The pattern of the matrix consists of 10 times 14 squares of one millimetre. Each of these squares is divided in 16 smaller squares.

Silver-working

A piece of pottery was found at the *terp* that could be a cupel-fragment (cupellation can be used to separate silver from lead or to purify gold[4]). The surface is purple and porous. The pottery sherd still needs to be analysed to be able to determine whether it actually is a cupel-fragment.

Other evidence for silver-working consists of four silver ingots. Two have more or less the same measurements (fig. 2, d). One other ingot is of the same type, but is cut in half. These ingots are probably formed in open moulds, because one side is flat (the flat side would have been the upper side of the open mould). They are dated 475-550 AD[5]. The fourth ingot is long and thin.

Two silverdrops were found in a context with a golddrop and the touch-needle and date from 850-950. The third silverdrop is earlier (475-550) and was found in the vicinity of one of the silver ingots.

Copper-working

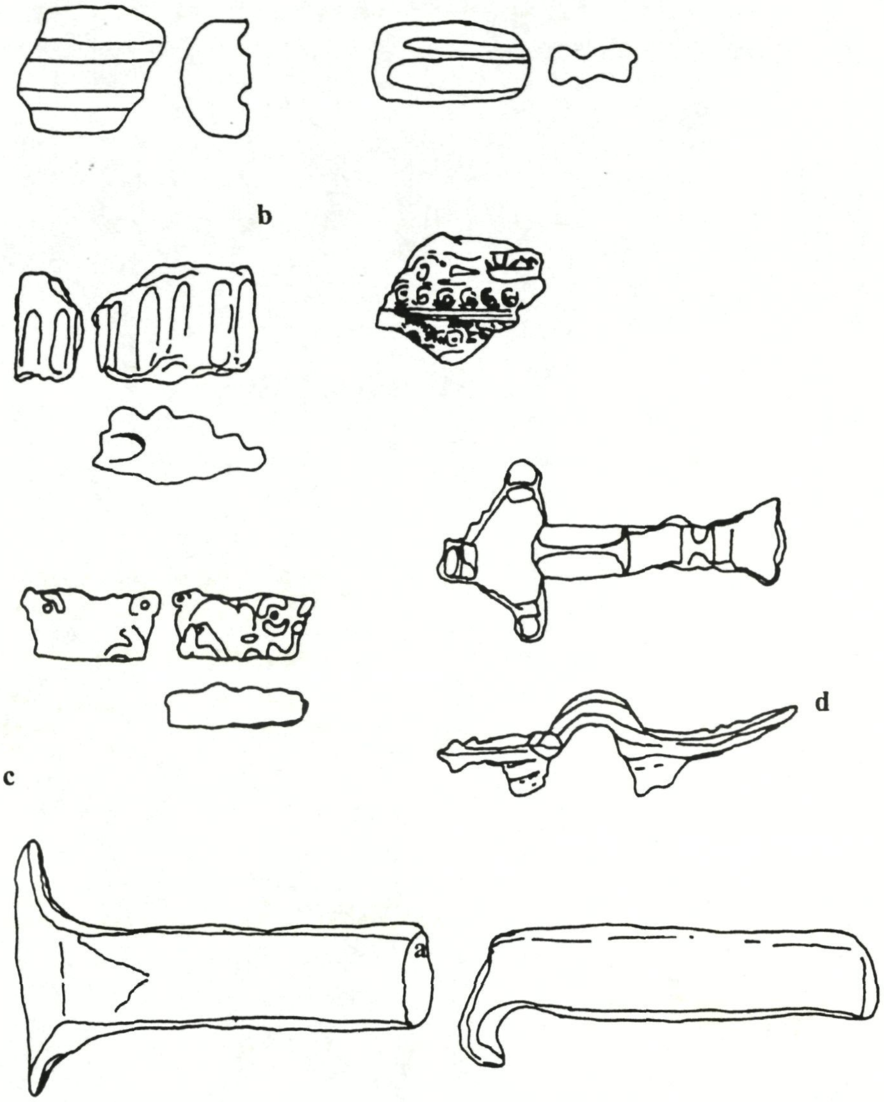
During the excavation many fragments of copper-alloys and pieces of lead were found. Lead and copper were in the same contexts, often together with fragments of crucibles and moulds. The lead could have been used for an alloy with copper or for making models for moulds.

3 See A.J. Nijboer & J. van Reekum (in print).

4 The lead oxidises to a litharge that can be taken off the melted metal or gets absorbed in the crucible. The silver is left in the form of a small lump at the bottom of the crucible (Tylecote 1992, 89; Bayley 1988, 194).

5 The form of these ingots can be compared to that of the one from Easingwold in York, although that one was dated in the Viking Age (Blackburn & Bonser 1990, 149).

Fig. 3. -
a) Copper ingots (J. de Koning);
b) Four moulds, one of which is decorated (J. de Koning, C. Tulp);
c) A model;
d) A semi-manufactured brooch (J. de Koning).



Copper objects were made by melting ingots, scrap metal or objects like Roman coins. There are a few copper ingots from Tjitsma, which have different shapes (for example fig. 3, a). Roman coins and fragments of coins were in some cases discovered among other copper fragments and lead. The same goes for some fragments of copper objects that were found in abundance at the *terp*. A lot of scrap metal was in the form of copper sheets. Sometimes these sheets were folded and some of them have cutting marks.

No complete crucibles were found, often only very small fragments. Because of this it is difficult to say anything about the size and form of the crucibles used at the *terp*. About half of the fragments were found in contexts with other evidence for metal-working. On some of the fragments traces of copper are visible.

Most of the moulds from Tjitsma have one or more grooves in the surface for making small bars (fig. 3, b). Many of these moulds are found in contexts with copper, lead and fragments of crucibles. There is only one fragment of a decorated mould. At Tjitsma one object was found that may have been a model (fig. 3, c). It is an object of lead and is decorated on both sides.

There are three semi-manufactured objects from the *terp*: two keys and one brooch. The brooch (fig. 3, d) still has the casting seams.

Iron-working

The iron ingots from Tjitsma are of several different forms. Two ingots consist of a folded sheet of iron (fig. 4, a). Two others (fig. 4, b) are flat (one has two folded edges and is called a ploughshare[6]). Another ingot is long and is round in cross-section. It is possible that this is a semi-manufactured object. The same goes for two flat, long ingots with a bent end (fig. 4, c).

6 Brown 1986, 313; Müller-Wille 1977, 143.

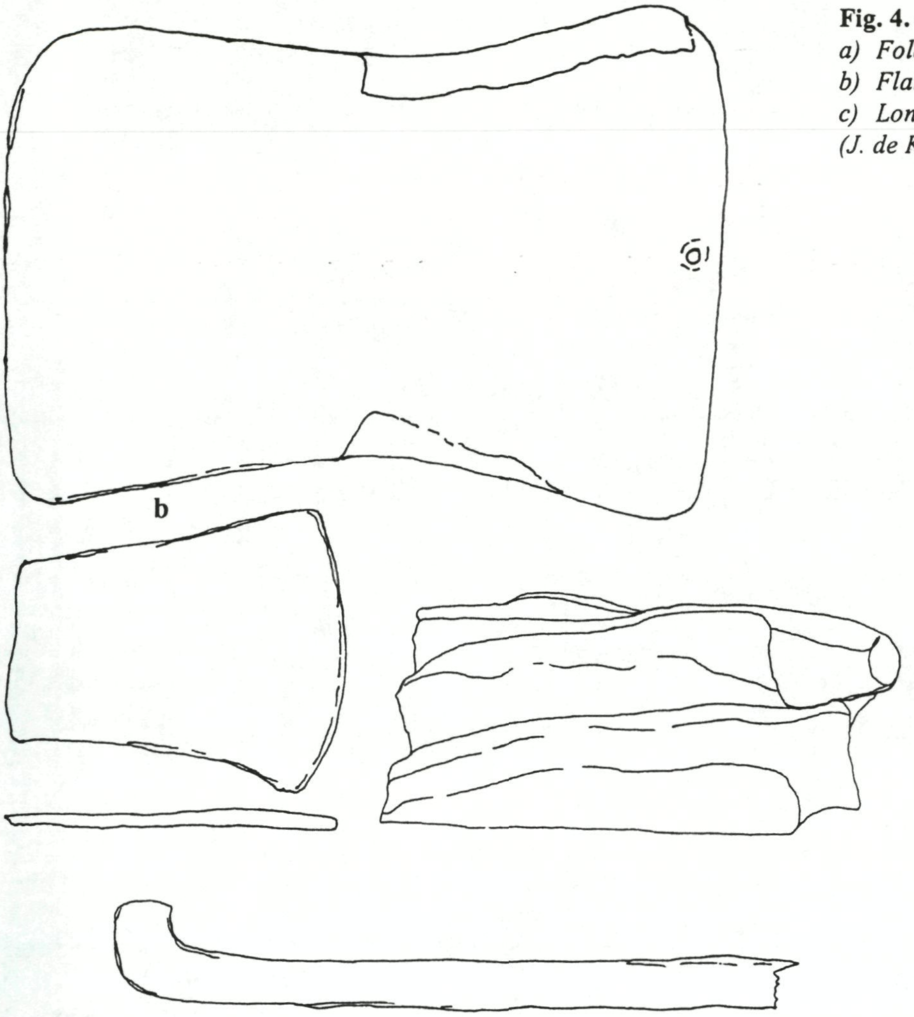


Fig. 4. -
a) Folded sheet of iron;
b) Flat iron ingots;
c) Long iron ingot with one bent end.
(J. de Koning).

Slags that derived from the production of iron have not been found during the excavation. The slags from Tjitsma are smithing-slags. Some slags are plano-convex and show the form of the base of the hearth.

In the same contexts as the slags and the material from hearths were some tuyère fragments. They were not parts of tubes, but were positioned between the fire and the bellows (fig. 5). This way they protected the bellows from the fire[7]. One side of the tuyère fragments is slag-like and vitrified. The other side is the outside and has not suffered from the heat that much. They are dated from 475-550 until 650-750 and are found in contexts with iron-slags and hearth-material.

[7] Brinch Madsen 1984, 29.

Fig. 5. - *The position of a tuyere (from: Scott 1990, 197).*

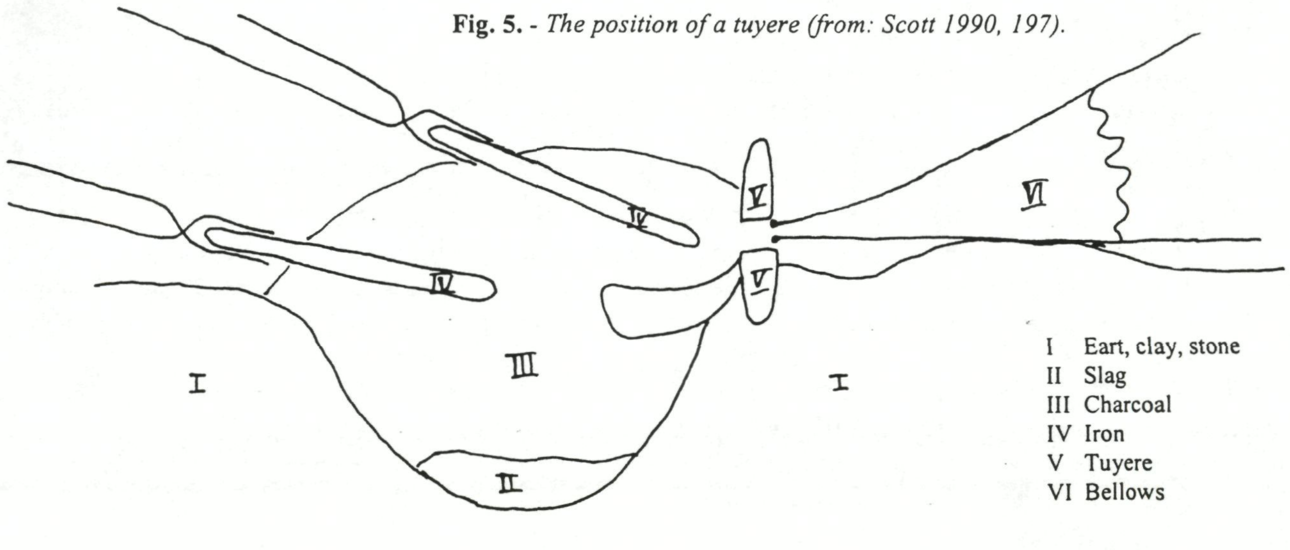


Fig. 6. - *Map of the site with the finds of the 2nd period.*

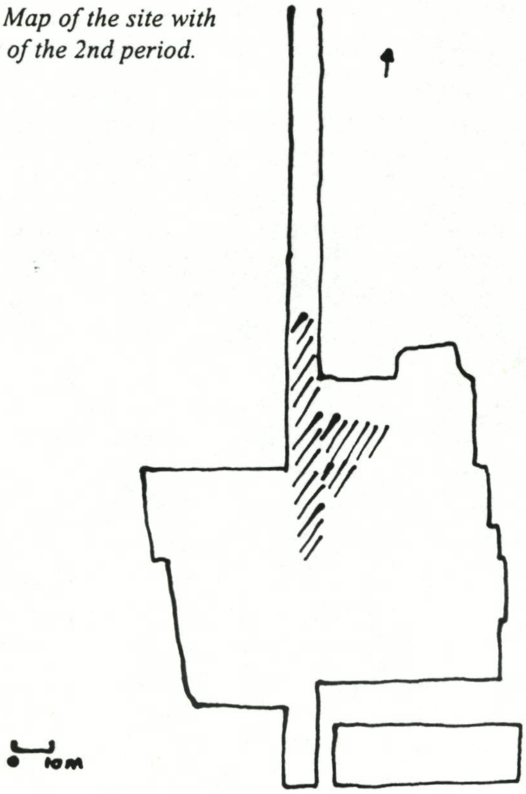
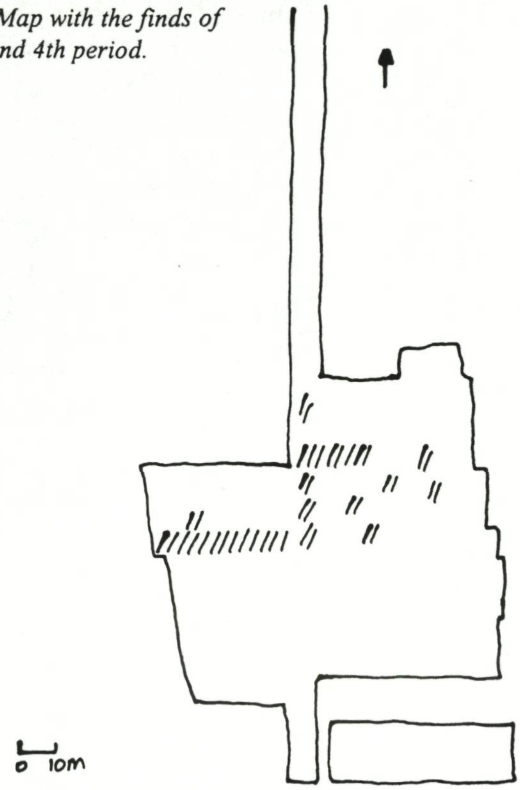


Fig. 7. - *Map with the finds of the 3rd and 4th period.*



There has been no trace of an anvil, but there is a concentration of hammerscale (usually found around an anvil). This concentration is found in a feature that is interpreted as the floor of the smithy. Except for the hammerscale and some copper and lead, the feature contained many pieces of iron. All the iron from the site is so corroded that it is very difficult to determine whether some of the pieces of iron are in fact semi-manufactured objects.

Fig. 8. - *Map with the finds of the 5th and 6th period.*

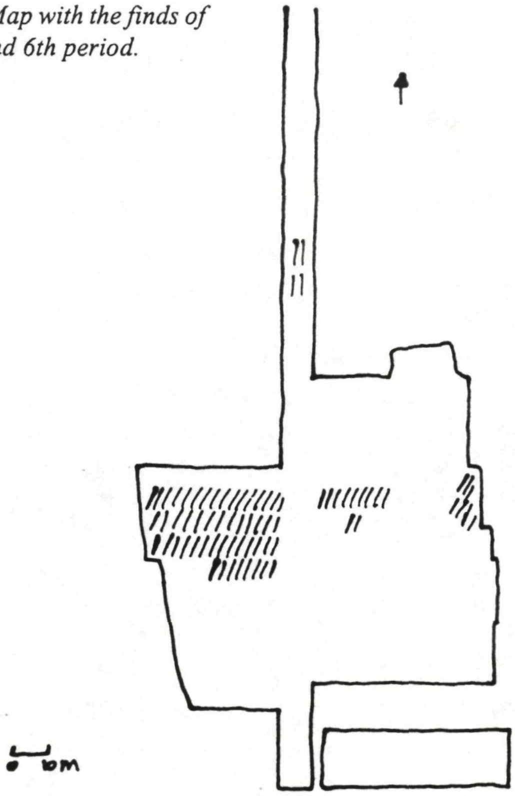
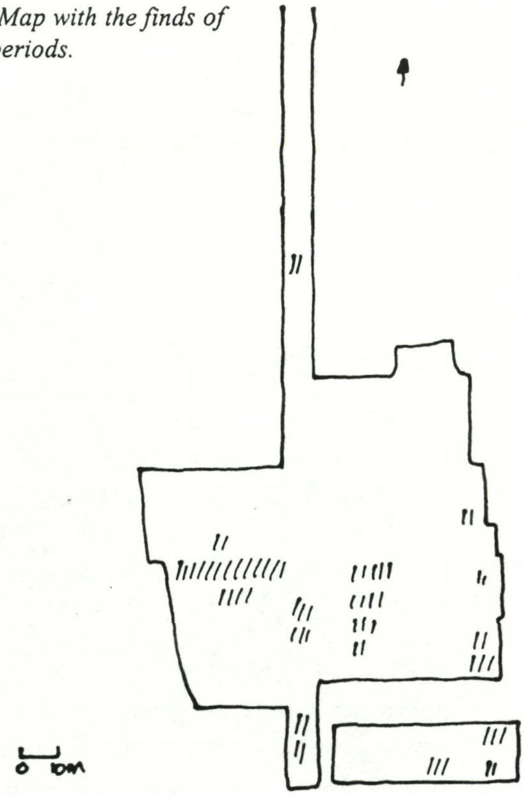


Fig. 9. - *Map with the finds of the last periods.*



Metal-working during the different periods

The occupation of Tjitsma is dated from 175 until 950 AD This period is divided into nine phases.

- In the first period (175-250 AD) only a few copper and lead fragments were found at the western side of the *terp*. There are no traces of iron-working and also no traces of gold- and silver-working. Only three silver coins date from this period, but these were not from a metal-working context.
- From the second period (250-300 AD; fig. 6) date some iron-slags found in the northern part of the *terp*. Here is where the floor of the smithy was also discovered. It was situated at the corner of a small podium built of sods (next to a larger podium with a house). Near the smithy was a well. Except for the small amount of iron-slags, much other evidence for metal-working was found near the smithy: a lot of fragments of copper, four hearths, crucible sherds, an ingot, and some lead.
- In the third period (425-475 AD; fig. 7); after the Migration Period), the metal-working was moved from the north of the *terp* to the western side. There is still only little evidence for iron-working, but many pieces of copper, lead, a mould, and some sherds of crucibles came to light here.
- The following period (475-550 AD) gives a clearer concentration of metal-working finds: a hearth, a silverdrop, an ingot of silver, many fragments of crucibles, a mould, copper, a lot of lead and many iron-slags. The people lived on the eastern part of the *terp* during this time. Some finds also come from this part, like the gold mounting and a little goldsmith-hammer. Some slags were also found on the eastern part, but no concentration was visible.
- Most of the metal-working finds are from the fifth period (550-650 AD; fig. 8). The metal-working is still concentrated at the western side of the *terp*. Here is also a well containing a lot of iron-slags and copper. Crucibles and moulds were also found at this part of the *terp*.
- In the next period (650-750 AD), the traces of both iron- and copper-working decreased. A few crucible sherds are found, but no moulds. The oldest iron ingot is from this period (although the iron-working is diminishing). There are traces of metal-working on the eastern part of Tjitsma: the goldwire, the crucible sherd with tiny golddrops and a part of a balance were found here. There is, however, no concentration of finds.
- In the seventh period (750-800/850 AD; fig. 9), the evidence for metal-working further decreases. The finds are more scattered over the *terp*. Two iron ingots were found at its southern end for example.
- From the period 800-850 AD dates the touchstone found in a well. Finds related to metal-working no longer occur at the western side of the *terp*, but there are more of them at the centre (such as three iron ingots) and at the southern side. The traces of occupation increase while those of metal-working decrease.
- In the last period (850-900/950 AD), most of the metal-working finds consist of fragments of lead. Only to the south of the *terp* silverdrops, a golddrop and the touch-needle are found.

At Tjitsma there has been no mass production as for example at Helgö, but metal-working was important at the *terp*. Although the smiths were working in areas of the *terp* where no people were living, they occupied a large part of the *terp*.

The finds that had something to do with gold- and silver-working and the large amounts of copper point towards the presence of an elite near Wijnaldum during the early Middle Ages. Whether part of the elite actually lived at Tjitsma or at another *terp* in the vicinity is difficult to say. In any case, the metal-working took place at the *terp* Tjitsma during many centuries.

Literature

ANDERSSON K. 1995: *Romartida Guldsmide i Norden III. Övriga smycken, teknisk analys och verkstadsgrupper*, Doctoral Thesis, Uppsala.

BAYLEY J. 1988: Non-ferrous metalworking: continuity and change, in: E.A. SLATER & J.O. TATE (eds.), *Science and Archaeology Glasgow 1987. Proceedings of a Conference on the Applications of Scientific Techniques to Archaeology. Glasgow, September 1987, Part I*, B.A.R. British Series 196 (I), Oxford, 193-208.

BESTEMAN J.C. & BOS J.M. & HEIDINGA H.A. 1993: *Graven naar Friese koningen. De opgravingen in Wijnaldum*, Franeker.

BLACKBURN M.A.S. & BONSER M.J. 1990: Viking-age silver ingot from near Easingwold, York, *Medieval Archaeology* 34, 149-150.

BRINCH MADSEN H. 1984: Metal-casting. Techniques, production and workshop, in: M. BENCARD, *Ribe Excavations 1970-76*, 2, Esbjerg, 15-90.

BROWN K. 1986: *The Development of Metalworking in Britain and the North Sea Littoral from the Late Roman Iron Age to the Early Medieval Period,* Thesis, Oxford.

JANSSEN W. 1991: Das fränkische Gräberfeld von Wesel-Bislich. Bericht I, *Zeitschrift für Archäologie des Mittelalters* 18/19, 71-116.

MÜLLER-WILLE M. 1977: Der frühmittelalterliche Schmied im Spiegel skandinavischer Grabfunde, *Frühmittelalterliche Studien* 11, 127-201.

NIJBOER A.J. & REEKUM J. VAN (in print): An examination of the golden disc-on-bow brooch from Wijnaldum, in: J.C. BESTEMAN & J.M. BOS & D.A. GERRETS & H.A. HEIDINGA (eds.), *The Excavation near Wijnaldum. Reports on Friesland in Roman and Medieval Times*, First Volume.

SCOTT B.G. 1990: *Early Irish Ironworking*, Ulster Museum Publication nr. 266, z.p..

TYLECOTE R.F. 1992[2]: *A History of Metallurgy*, London.

Caroline Tulp
Hiddemaheerd 93E
N - 9737 JW Groningen
Netherlands

Marta Sancho i Planas

La producción de hierro en el establecimiento siderúrgico de Fabregada (PrePirineo Catalán) en la Edad Media (siglos XI-XIII)

Introducción

El texto que presentamos a continuación, intentan recoger el estado de las investigaciones que han sido realizadas, hasta este momento, a cerca del yacimiento de *Fabregada.* Después de siete campañas de trabajos de campo, dos de prospección y tres de intervención arqueológica, algunos de los aspectos que nos planteamos, al inicio de la investigación, estan aún en proceso de estudio. A pesar de ello, hemos considerado oportuno presentar los resultados obtenidos, tanto por su singularidad como por tratarse de un buen punto de partida para llevar a cabo nuevas investigaciones en historia y arqueología medieval.

En muchos casos, los resultados que aquí presentamos deberán ser contrastados y matizados a medida que proliferen estudios de estas características. El tema central de la investigación y la metodología que hemos aplicado así lo exigen y esperamos que así sea. Por nuestra parte, consideramos dichos resultados como propuestas sobre las que se deberá continuar investigando, con el fín de profundizar sobre este aspecto clave de la tecnología medieval que es la producción de hierro.

Ciertamente no resulta aconsejable estudiar este tema como un hecho aislado, sín conexiones con su entorno social, y es por eso que hemos intentado encuadrar los aspectos más técnicos dentro de su marco histórico, en las coordenadas espacio-temporales que le corresponden. Finalizaremos esta comunicación con las propuestas de futuro que deben dar continuidad a la investigación, algunas de las cuales se encuentran, ya, en proceso de estudio.

Ambito geográfico

El yacimiento de *Fabregada* se encuentra situado en la vertiente norte de la sierra del *Montsec d'Ares.* El *Montsec* forma parte de las sierras exteriores prepirenaicas y es el límite natural entre el *Pallars* y la *Noguera.* En él transcurren los rios *Noguera Ribagorçana* y el *Noguera Pallaresa* que, de poniente a levante, dividen la sierra en tres: *Montsec d'Estall, Montsec d'Ares* y *Montsec de Rúbies* y configuran los desfiladeros de *Mont-rebei* y *Terradets.* Su longitud total es de 45 km. y su anchura oscila entre 4,5 i 10 km., con una altura máxima de 1684 mts. en la cima de *Mira Pallars* en el *Montsec de Rúbies* y de 1678 mts. en la cima del *Santalís* en el *Montsec d'Ares* (Fig. 1).

La sierra del *Montsec* se nos presenta como una zona de frontera en varios sentidos. Frontera bioclimática que afecta tanto a la vegetación como a la fauna; frontera socio-económica y cultural entre el llano y la montaña; y, alrededor del año mil, frontera política entre la marca superior de Al-Andalus y los condados pirenáicos de *Urgell* y *Pallars.* En todos estos aspectos la frontera actua, al mismo tiempo, como línea divisoria y zona de contacto, lo cual le proporciona una gran riqueza y variedad que puede observarse a todos los niveles, tanto naturales como socio-culturales.

Las características propias de los climas mediterraneo y atlántico tienen, en el *Montsec,* su límite septentrional y meridional respectivamente. Esta interacción incide directamente en la fauna y la vegetación de tal forma que es posible encontrar especies propias de uno y otro ámbito climático. A nivel socio-cultural, la confluencia entre el llano – representado por los valles del *Segre, Noguera Pallaresa* y *Noguera Ribagorçana* – y la montaña que supera los 1.600 mts. de altitud, es bien visible en las oposiciónes entre agricultura y ganadería, buenas y malas comunicaciones, inmigración y emigración, etc. por poner sólo algunos ejemplos.

Fabregada forma parte actualmente del municipio de *St. Esteve de la Sarga* en la comarca del *Pallars Jussà* (Cataluña). Se encuentra situado en un punto de confluencia de caminos y cañadas, ya documentados en el s. XI. Concretamente el *camí ral* que sigue todo el valle de *St. Esteve* xy que, por la collada de *Fabregada,* comunica las cuencas del *Noguera Pallaresa* y del *Noguera Ribagorçana,* dentroedel territorio bien definido del castillo de *Mur.* La otra

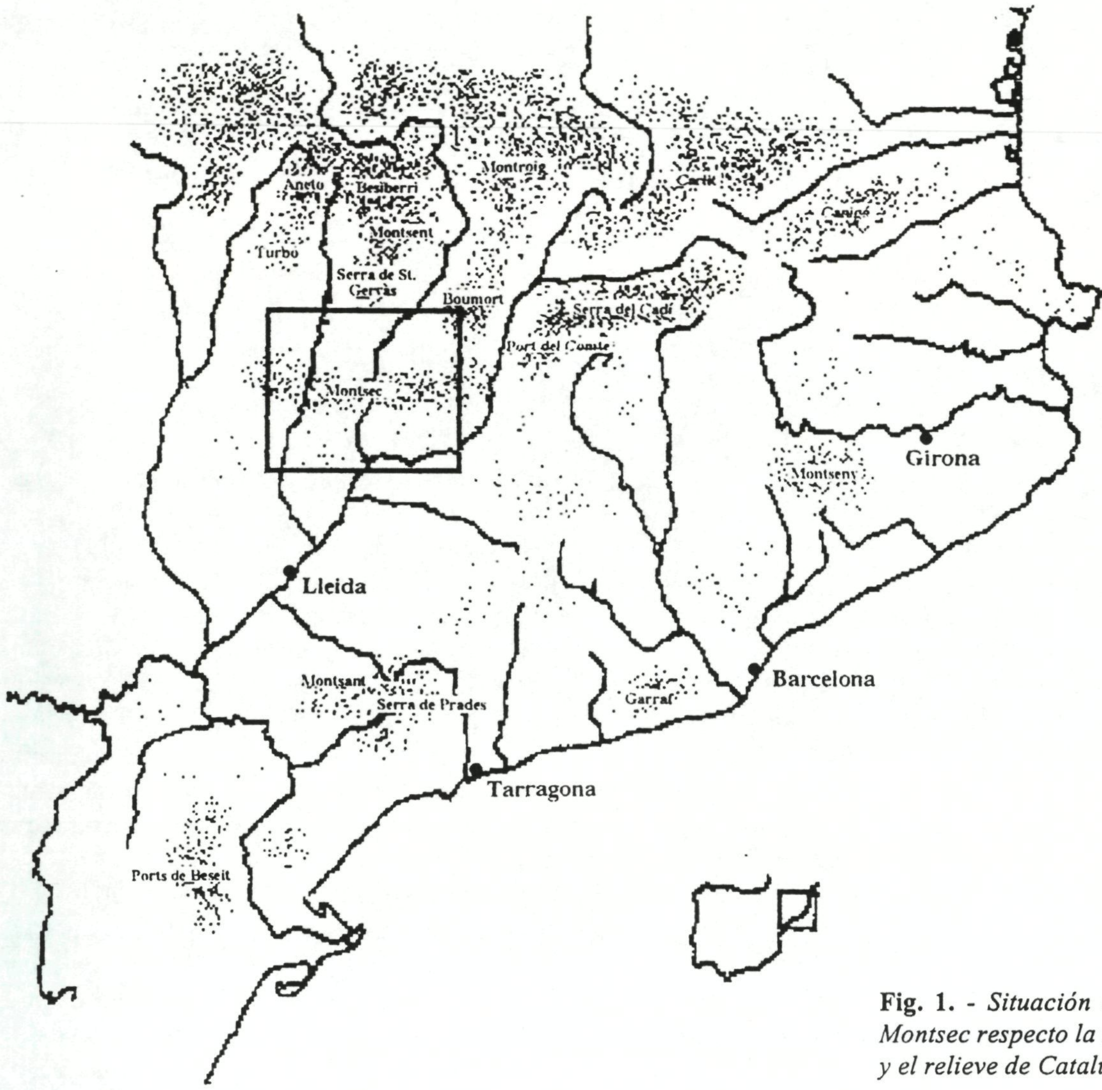


Fig. 1. - *Situación de la sierra del Montsec respecto la red hidrográfica y el relieve de Cataluña.*

vía de comunicación, es el camino-cañada que, procedente de *Àger*, en la cara sur del *Montsec*, salta la carena por la collada de *Ares* y va a *St. Esteve*, para continuar hacia el norte por las carenas en dirección al *Meüll*, camino de los *Pirineos*.

El Montsec en la Edad Media

A lo largo de los siglos X y XI, el Montsec fué un teritorio de frontera, con unas condiciones naturales óptimas para organizar una línea defensiva frente al peligro que representaba el Islam (Fig. 2).

De los rios *Noguera Ribagorçana* hasta el *Segre*, la sierra del *Montsec* se convirtió en una verdadera muralla natural entre musulmanes y cristianos, con cuatro únicos pasos practicables con cierta facilidad:

- El *Pas Nou:* entre los valles del *Segre* y la *Noguera Pallaresa*
- El pas de *Terradets:* sigue el curso de la *Noguera Pallaresa* en dirección N-S
- El *Coll d'Ares:* supera el *Montsec d'Ares* por este puerto de montaña
- El desfiladero de *Montrebei:* sigue el curso de la *Noguera Ribagorçana* en dirección N-S

Los cuatro pasos citados presentan fortificaciones, castillos o torres, tanto en la vertiente sur como en la norte. En el *Pas Nou*: *Vilanova de Meià, Castell de Fabregada*[1] y *Sta. Anna.* En *Terradets*: la baronia de *San t Oïsme* y la torre de l'Ametlla al sur y *Llimiana* y los castillos de *Guardia* y *Mur,* al norte. El *Coll d'Ares*: con *Ager* y *Sant Llorenç d'Ares* al sur y *Alsamora* al norte. Finalmente *Montrebei*: donde encontramos el castillo de la *Pertusa* en su entrada por el sur y los castillos de *Xiribeta* y *Alsamora* en el lado norte.

[1] No se trata del yacimiento de Fabregada objeto de este artículo sino de otro lugar donde aparece el mismo topónimo, situado cerca de Vilanova de Meià, en el extremo más oriental de la sierra del Montsec.

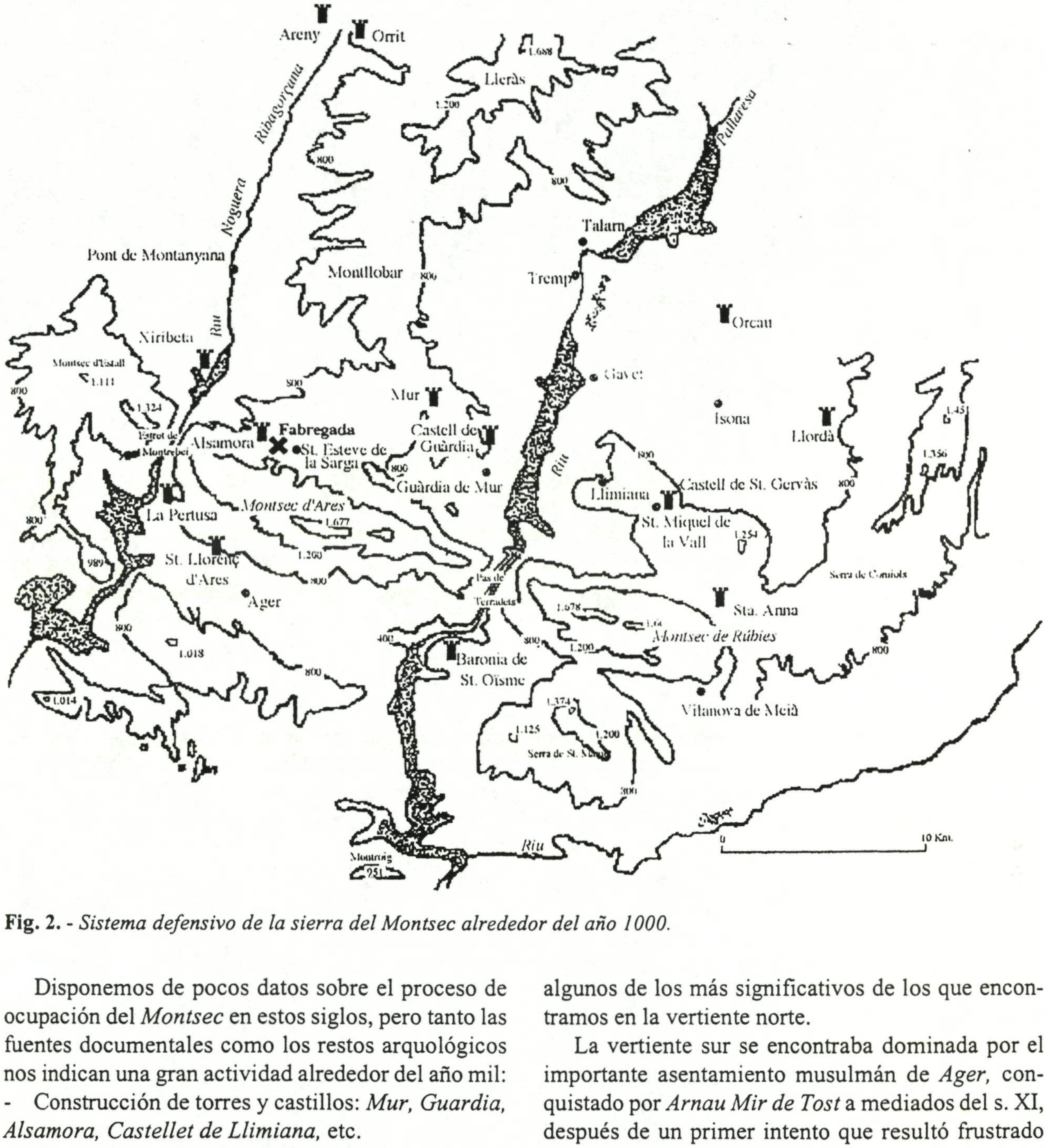


Fig. 2. - *Sistema defensivo de la sierra del Montsec alrededor del año 1000.*

Disponemos de pocos datos sobre el proceso de ocupación del *Montsec* en estos siglos, pero tanto las fuentes documentales como los restos arquológicos nos indican una gran actividad alrededor del año mil:

- Construcción de torres y castillos: *Mur, Guardia, Alsamora, Castellet de Llimiana,* etc.
- Organización de núcleos de hábitat: *Fabregada, San tMartí de Barcedana, Moror, San tEsteve de la Sarga, Alzina,* etc.
- Presencia de la Iglesia a través de la construcción y dotación de nuevos templos, la mayoría de ellos aún conservados: *Sant Salvador de la Serra, Sant Feliu de Guardia o Sant Roc de la Mata-Solana,* etc. a las que debemos añadir las iglesias de cada uno de los lugares y castillos antes señalados.

A esta relación de núcleos habitados, debemos añadir aquellos que fueron abandonados y de los que tan solo se conserva el topónimo y algunos vestigios que esperan una investigación arqueológica: El *Cuscó, San Martí de les Tombetes, el Serrat de la Capella, Vilamolera, Santa Anna,* etc. por citar tan solo algunos de los más significativos de los que encontramos en la vertiente norte.

La vertiente sur se encontraba dominada por el importante asentamiento musulmán de *Ager,* conquistado por *Arnau Mir de Tost* a mediados del s. XI, después de un primer intento que resultó frustrado por los muslmanes. La ocupación cristiana del sur del Montsec, vendrá condicionada por la conquista militar de estos territorios. En este proceso de ocupación debemos señalar los siguientes núcleos de hábitat: *Sant Llorenç d'Ares, la Régola, la baronia de Sant Oïsme, la Pertusa, Corçà,* etc.

Actividades productivas y organización del territorio en el valle de San Esteve

Si nos centramos concretamente en el valle de *Sant Esteve,* observaremos que el paisaje viene dominado por el bosque y los pastos más que por los campos de cultivo, que quedan limitados en las zonas más bajas del valles y en el lado de la solana. Cerca de los torrentes encontramos pequeñas terrazas relacionadas con simple pero efectivas infraestructuras hidráulicas; pequeñas presas para desviar el agus hacia canales excavados en la roca o construidos de forma sencilla y balsas para recoger el agua construidas, siempre, aprovechando os desniveles del terreno. Estas terrazas de regadio habían estado ocupadas por huertos hasta hace poco más de 30 años. La pregunta que nos hacemos es ¿Desde cuándo?

En algunas ocasiones la presencia de caminos empedrados de tipología medieval, nos permite especular sobre su origen. Las balsas y los canales excavados en la roca también parecen indicar esta cronología. El mismo tipo de caminos los podemos encontrar en los alrededores de todos los pueblos del valle, pueblos que aparecen documentados a lo largo del s. XI. La mayoría de estos caminos se encuentran en un total estado de abandono y en algunos casos muy perdidos, pero aún es posible seguir algunos de ellos hacia el fondo de los torrentes donde encontramos, además de los huertos, algunos molinos harineros. Una vez más debemos plantearnos su cronología de origen ya que, en todos los casos sabemos que fueron utilizados hasta hace poco más de treinta años.

Sobre los molinos diponemos de una información documental y arqueológica muy interesante. Se trata de un documento de 1075 en el que aparece citado el lugar de *Vilamolera.* Cerca de este lugar, se encuentra una cantera de piedras de molino en la que pueden observarse los negativos de las ruedas extraidas. Otro tipo de instalación relacionada con la transformación de productos alimentarios, son la prensas de aceite, situadas cerca de los pueblos y comunicadas con ellos a través de caminos de las mismas características que los ya citados.

A lo largo de todo el valle podemos observar un gran número de corrales comunicados entre sí por una red de caminos ganaderos, delimitados con muros de piedra seca a cada lado, para evitar que los rebaños entren en los campos cultivados. El trazado de estos caminos suele seguir una linea recta y en muchas ocasiones los encontramos siguiendo las carenas con lo que se convierten en vias rápidas de comunicación dentro del territorio. Estos caminos suelen comunicar los pueblos y corrales con los pastos situados fuera de las mejores tierras aptas para el cultivo; yermos y bosques convenientemente señalados con mojones, *cussols* y *pilarets.* En estos lugares son habituales las pequeñas cabañas de pastor, construidas con piedra aprovechando los desniveles del terreno. La producción de lana, documentada para la zona en el s. XI, nos permite especular sobre la organización del terriorio alrededor de esta actividad ganadera.

Los testimonios de actividades productivas que se remontan en el tiempo incluyen, también, canteras de losas, puntos de extracción de yeso, y es posible encontrar antiguos hornos de cal y yeso de los que aún se conserva la memoria. ¿Desde cuándo fueron explotados todos estos recursos?

Algunos de ellos, como las canteras de piedra y losas, obligatoriamente fueron explotados en época medieval. Buena prueba de ello eran los vestigios de la iglesia del *Serrat de la Capella* hoy desaparecidos. Otros como el yeso y la cal, sólo fueron utilizados en las construcciones civiles, militares y religiosas, como puentes, castillos e iglesias. Los analisis de los morteros de estos edificios podrían facilitar alguna respuesta a esta cuestión.

No hemos hablado aún de la explotación del bosque, tanto para la obtención de madera para la construcción, la fabricación de utillage, objectos del hogar y otros utensilios, como para obtener la energía calorífica, en forma de leña o carbón. Debemos tener en cuenta otras actividades como la recolección de frutos, la producción de pez y el aprovechamiento de ciertas especies vegetales para fines diversos. Entre estas actividades la que ha dejado una huella más profunda y unos vestigios más visibles, ha sido la producción de carbón. Además de topónimos como el barranc de carboners o la *fonte carbonella,* documentada en 1010, encontramos numerosas plazas de carboneo diseminadas por las zonas boscosas de todo el *Montsec.* Lógicamente podemos establecer una relación directa entre la producción de carbón y la industria siderúrgica que estamos estudiando, por lo que no dudamos en asegurar que, por lo menos desde el s. XI, los bosques del *Montsec* eran objeto de este tipo de explotación.

Vemos, pués, como la actividad productiva del *Montsec,* alrededor del año mil, estaba muy diversificada. La necesidad de autoabastecimiento de la comunidad de pobladores, requería este esfuerzo. A partir de este ejemplo, consideramos que el mundo rural medieval, presenta una gran variedad de actividades productivas lo que nos da una visión no tan exclusivamente agrícola como los estudios documentales permiten suponer.

Desconocemos el grado de especialización y el nivel de intercambios de productos dentro del mismo valle y con otros lugares más alejados. Constatamos la falta de algunos productos básicos del mundo medieval, como la sal. Cabe pensar que la imposibilidad de producir sal, propició contactos e intercambios con centros productores com *Gerri de la Sal* [2].

---

2 Monasterio situado unios 50 Km. más al norte que destaca por la producción de sal y del que se conserva un documento

Fabregada y su articulación con el territorio

De todas las actividades señaladas, la producción de hierro es, sí duda, la más compleja y especializada. El hierro es el material de uso dominante en toda la Edad Media. Su utilización en la fabricación de armamento y herramientas diversas lo convierten en un material estratégico, muy apreciado e imprescindible para el buen funcionamiento de una comunidad. La complejidad del proceso provoca un grado de especializació elevado y permite, a los centros productores, subsistir casi exclusivamente de esta actividad.

Esto es lo que se desprende de nuestra investigación. *Fabregada* es un lugar dedicado a la actividad siderúrgica, que aparece documentalmente definido en la donación que el conde *Ramon IV de Pallars* hizo a uno de sus más fieles vasallos, *Bertran Ato de Montayana,* en 1038. En esta donación, se establecen unas afrontaciones que limitan el término de *Fabregada* a una estrecha fraja de territorio, situada entre *Alsamora* al oest y *Sant Esteve* al este, ambos a poco más de 1 Km. de distancia. Sobre el terreno, podemos obsevar como *Fabregada* carece de tierras buenas y aptas para el cultivo y pastos. Actualmente la única zona donde encontramos campos de cultivo cerca de *Fabregada,* es donde se situa uno de los escoriales del establecimiento siderúrgico. Podemos decir que *Fabregada* no disponía de otros recursos que no fueran la producción de hierro, por lo que debía ser suficiente para, a través de pequeños intercambios mantener a la comunidad.

Después de la donación de 1038, *Fabregada* permanecerá vinculado a la familia de los señores de *Montanyana* y, por lo tanto, se encontrará limitanto con el termino occidental del castillo de *Mur,* centro administrativo de todo el territorio de la vertiente norte del Montsec de Ares.

El año 1076, *Bertran de Montanyana* y *Ermengarda* aparecen como constructores de la igleisa de *Sant Esteve de la Sarga,* posiblemente un nuevo templo que substituiría el antiguo del cual parecen conservarse algunos restos en el edificio actual. En el acta de dotación de dicha iglesia, los *Montanyana* hacen donación de un tercio del diezmo de *Fabregada.* Teniendo en cuenta que *Fabregada* producía principalmente hierro, es de suponer que esta parte del diezmo se pagaría, precisamente con hierro, lo que haría muy atractivo el control de esta parte del diezmo. En resumen, durante el s. XI *Fabregada* aparece como un pequeño núcleo de hábitat concentrado, dedicado a la producción de hierro, controlado por los señores de *Montanyana* y vinculado a *Sant Esteve de la Sarga* por el pago de un tercio del diezmo que generaba.

Fases del trabajo de investigación

El estudio sobre la producción de hierro en la Edad Media al sud del Pirineo Catalán se inició en el año 1990 con una planificación de los trabajos a realizar a partir de la combinación de dos tipos de fuentes y dos metodologías de trabajo diferentes: fuentes documentales y fuentes arqueológicas. Esta complementariedad de las fuentes la consideramos absolutamente necesaria para poder abordar un tema poco trabajado en la historiografía catalana y en el que intervienen múltiples aspectos relacionados con la tecnología aplicada al proceso de producción, impacto en el medio, organización del trabajo, propiedad de las *fargas*,[3]...

El estudio se inició con un vaciado exhaustivo de la documentación publicada desde el siglo IX al XIII y que afectase al ámbito estudiado. Este trabajo nos tenía que facilitar la localización de establecimientos siderúrgicos que posteriormente serían situados sobre la cartografía correspondiente y, en caso de ofrecer posibilidades, podrían ser localizados sobre el terreno. La revisión de documentación ha afectado, finalmente, a un volumen superior a los 11.000 documentos, de los cuales se han podido utilizar 139, obteniendo un total de 78 *fargas* citadas de entre los siglos IX-XIII para el territorio comprendido entre los Pirineos y el río Ebro en la zona catalana. De estas *fargas*, tan sólo cuatro presentaban las condiciones suficientes para intentar una localización *in situ* y sólo una, *Fabregada*, ha sido finalmente localizada.

El proceso de localización sobre el terreno se hizo después de un trabajo cartográfico intenso, con cartografía a escala 1: 50.000 y fotografía aérea a escala 1: 25.000, 1: 5.000 y 1: 2.000. Los datos extraídos de la documentación se fueron contrarrestando con la información toponímica y sobre mineraliza-

falso en el que se reclaman unos pretendidos derechos sobre una parte del diezmo de Sant Esteve de la Sarga, al que correspondía parte del diezmo de Fabregada. Posteriorente, en una relación de bienes perdidos por el monasterio, aparecerá reseñada esta parte del diezmo.

[3] El término *farga* aparece en la documentación medieval como *fabrica, fabrega, fabricata, farga,* y debemos interpretarlo, dentro del contexto catalán, como un establecimiento siderúrgico dedicado a la reducción de óxidos de hierro a hierro metálico a partir del sistema directo, usando como reductor carbón de leña.

ciones de óxidos de hierro para poder confeccionar una cartografía específica para cada una de las *fargas*.

La prospección sobre el terreno se realizó durante los veranos de 1990 y 1991, en la zona escogida, donde se localizaron grandes cantidades de escoria de hierro en los campos cercanos al yacimiento, las estructuras de un poblado y de un establecimiento siderúrgico o *farga* situado cercano a un torrente, y las estructuras de defensa del conjunto, muralla y foso. De todo el conjunto, tan sólo queda en pie la iglesia de la *Mare de Déu de Fabregada*, de gran devoción en la comarca, un edificio del siglo XII de pequeñas dimensiones situado fuera del poblado en la zona este.

En el año 1992 se iniciaron las campañas arqueológicas, limitadas a una duración de 20 días durante los meses de verano, y realizadas por un equipo preparado específicamente para la intervención en un yacimiento de estas características.

Resultados del trabajo arqueológico

Hasta el momento podemos diferenciar tres sectores:
- Sector 100: Zona industrial o *farga*.
- Sector 200: Zona poblado; sistema defensivo.
- Sector 300: Zona de vertedero de escorias.

La mayor parte del trabajo arqueológico realizado hasta el momento se centra en el sector 100, por lo que nos limitaremos a exponer los resultados obtenidos en dicho sector. Las dos últimas campañas se han centrado en el sector 200 por lo que esperamos obtener resultados a corto plazo. De dicho sector tan solo señalar la gran cantidad de objetos de hierro que hemos podido recuperar en muy buen estado de conservación, lo que nos permitirá establecer una tipología muy interesante .

La zona industrial o *farga* se encuentra situada fuera del recinto del poblado existe una hilera de casas paralela al torrente de Sant Esteve. El edificio motivo de nuestro estudio está situado aproximadamente a unos 25 metros de la última casa, al sudoeste del poblado, y mide 7,5 x 5,5 metros. Se adapta a la inclinación del terreno y está construido sobre la vertiente izquierda del torrente (Fig. 3 y 4)

La localización en este sitio de un depósito de mineral de hierro, carbones, pequeños fragmentos de escoria y hierro metálico, tierra cocida y cerámica gris medieval que podemos situar entre los siglo XI i XII, nos indicaba ya una cierta actividad que tendría que estar relacionada con la reducción de mineral.

El ancho de sus muros es de 45 cm., construídos con piedras calcarias de la zona sin ningún tipo de retoque o pulimentación y de tamaños diversos. Entre las piedras no hay mortero, aunque éstas aparecen unidas mediante barro. El muro oeste se une al del sud en una esquina construída con piedras de gran tamaño, pero aproximadamente a 2,20 metros se pierde el muro original construído con barro para continuar con piedra colocada en seco, correspondiente a una remoción posterior muy tardía. Esta misma técnica la encontramos en el muro norte, el cual se cimienta, en parte, sobre el nivel de destrucción de la estructura medieval. Sólo en un pequeño tramo, situado en el ángulo NE, volvemos a encontrar parte de la construcción original con barro entre las piedras. Esta técnica constructiva la podemos observar, también, en el muro este, el cual se une al sud mediante una esquina construída con piedras de gran tamaño, similares a las que encontramos en el ángulo SW.

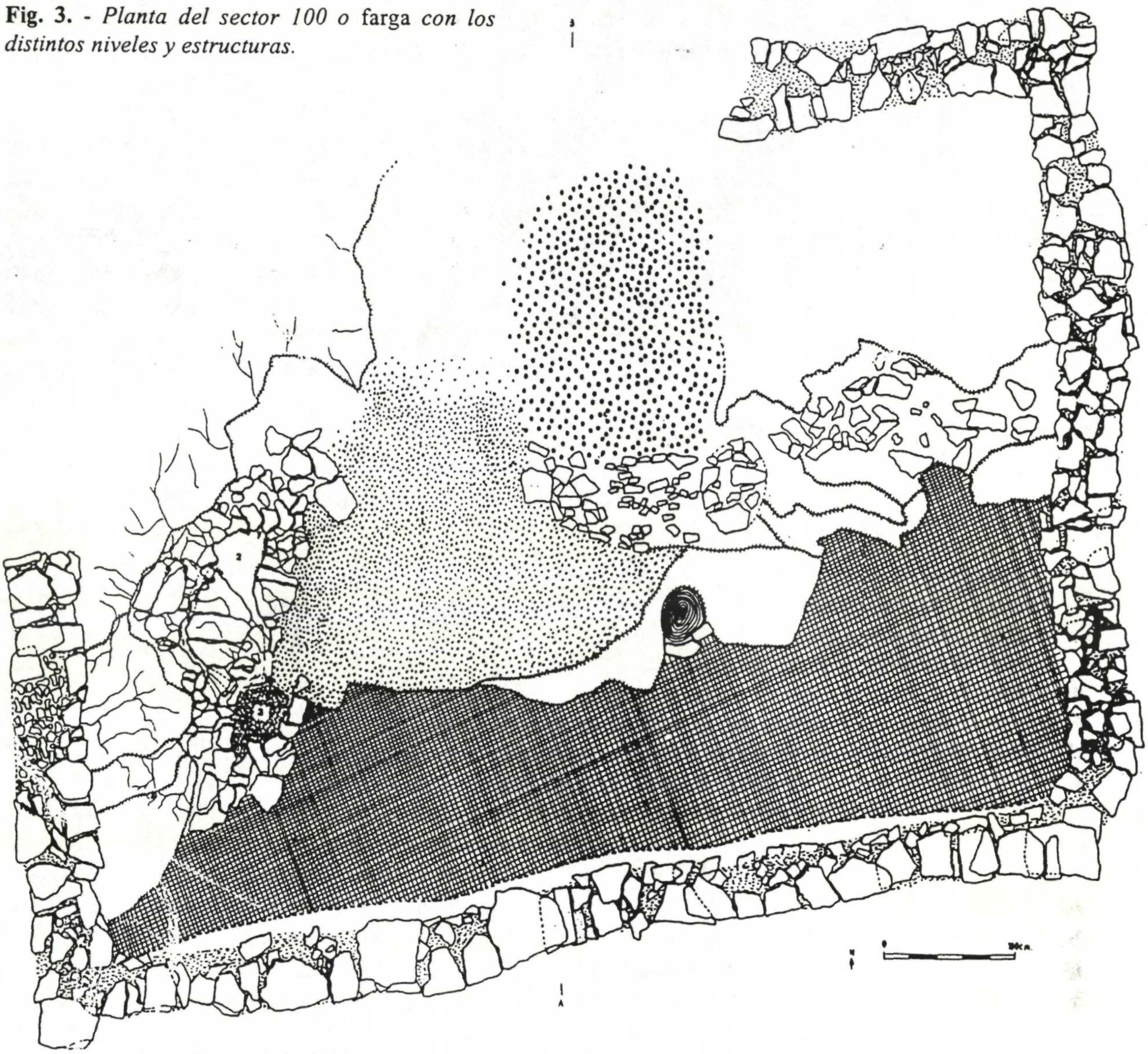
El edificio se asienta directamente sobre la roca madre siguiendo el desnivel natural de la misma, el cual forma dos escalones que siguen la dirección E-W y que dividen el espacio en tres ámbitos, más elevados en el norte que en el sur. Aprovechando el escalón más alto y adosado al muro este, se conservan los cimientos de una pared medianera que discurre hasta el centro del edificio, muy cerca del horno. Esta pared delimita un espacio que fue usado como almacén de mineral y lo separa de la zona de trabajo más cercana al horno. En es te espacio se ha localizado un montículo de mineral formado por óxidos de hierro hidratados, principalmente gohetita, de textura granulada, color rojizo y mayoritariamente en forma de terrones polvorientos, más o menos duros, según su composición (Fig. 3 y 4, área marcada con redonditas)

El edificio medieval estaría completamente abierto por su lado norte a modo de cobertizo, lo cual facilitaría el acceso y, sobretodo, la evacuación de los humos. Entre la pared medianera, el muro oeste y el escalón más bajo se ha localizado un pavimento, en lo que sería el espacio central de trabajo, que rodea la estructura del horno (Fig. 3 y 4, área punteada). El pavimento, considerado zona de paso y acceso, está formado por pequeñas piedras para nivelar la roca y tierra pisada, de un color rojizo debido a la descomposición del mineral situado en una zona más alta y un poco más al norte.

En el ámbito situado más al sur y a un nivel inferior hemos podido identificar otro pavimento de las mismas características. En este caso su color es gris ceniza, debido a que se encuentra bajo la influencia de la salida del horno, por donde se evacuarían las escorias y los restos de la combustión (Fig. 3 y 4 , área con trama a cuadros)

El espacio interior se presenta en tres niveles situados en diferente altura, configurados a partir de los escalones naturales de la roca madre (Fig. 4). El

Fig. 3. - *Planta del sector 100 o* farga *con los distintos niveles y estructuras.*



nivel más alto es el situado más al norte, en el cual también se situa el depósito de mineral. En el segundo nivel situamos tres elementos: el horno, el pavimento de tierra batida con restos de mineral mezclados y la pared medianera. El tercer nivel presenta el pavimento de tierra, cenizas y carbones, situado directamente sobre la roca madre y en relación con la salida del horno, situado en el nivel intermedio y en una posición más elevada.

En este tercer ámbito encontramos diferentes elementos que, de este a oeste, són: en primer lugar, un escalón natural con señales evidentes de que la roca madre ha sido retocada para adecuar dos plataformas inclinadas en dirección al inicio del canal de aire. Consideramos posible que su utilidad estuviese marcada por la colocación de las manchas necesarias para insuflar el aire dentro del horno. A continuación encontramos el pozo de escorias o cubeta donde se depositarían las escorias sangradas del horno en diferentes momentos del proceso. Se encuentra en contacto con los dos pavimentos, donde el escalón es menos pronunciado, a pesar de que la zona de acceso se situaría en el nivel inferior, y aprovecha la pendiente natural del terreno para poder facilitar la evacuación de las escorias coladas.

A continuación y en la zona más amplia de este ámbito se situaría el martillo hidráulico, con la cabeza mirando al este. Esta interpretación se basa en la existencia, en este punto, de un encaje de 60 cm. de profundidad y 30 cm. de diámetro (Fig. 3, marcado con líneas concéntricas), delimitado por piedras, que se apoya directamente sobre el escalón que la roca forma entre la pared medianera y el pavimento interior. Este encaje es apto para soportar la infraestructura que comporta el martillo. Así mismo, encontramos pequeños encajes cuadrados trabajados en la roca que coinciden con una piedra del muro sur colocada transversalmente del interior al exterior, la cual relacionamos con el punto de entrada del eje motriz que accionaría dicho martillo pilón.

Los pocos restos que se conservan en este sector dificultan una interpretación más exacta de las características de este mecanismo, que cabe relacionar con los restos de la presa para retener el agua que se puede observar al exterior del edificio

Las estructuras del horno localizadas nos ofrecen una información bastante completa de sus características. Entre estas estructuras podemos diferenciar tres elementos:

- el horno (Fig. 3: 2)
- la entrada de aire forrzada (Fig. 3: 1)
- la salida y el pozo de escorias (Fig. 3, 3).

El horno presenta un muy mal estado de conservación debido a los efectos de las fuertes temperaturas y a la erosión provocada por la circulación del agua una vez abandonado todo el complejo. Se encuentra en una esquina que hace la propia roca natural, aprovechando sus desniveles y está medio excavado en la misma roca y medio construído con piedra caliza. La planta es ovalada, con un diámetro aproximado máximo de 60 cm. y mínimo de 40 cm. y la profundidad máxima que hemos podido calcular es de 61 cm. Desde el centro del horno hasta encima de las piedras que cubren la entrada de aire. En el fondo del horno, en el lado W – que es el mejor conservado –, se puede observar una banqueta que debía tener su paralelo al otro lado Entre las dos banquetas se inicia el canal de evacuación de escorias hacia el exterior del horno.

El canal de entrada de aire forzado presenta una anchura de entre 4 y 5 cm. y una longitud de 120 cm. Se inicia al lado del pozo de escorias, en un nivel un poco más alto, con una doble entrada para los fuelles, que estarían situados en las repisas inclinadas de la roca natural situadas al oeste. En este primer tramo el canal sigue la dirección SE-NW y aproximadamente en la mitad de su recorrido cambia de dirección (SW-NE) siguiendo una amplia curva que lo introduce en el horno. En su último tramo, 23 cm., se inclina considerablemente tomando un ángulo aproximado de entre 35° y 45° sobre el plano. Todo el canal está construído con piedras, entre las cuales se han encontrado fragmentos de mortero y recortes en la roca.

La salida de escorias se encuentra en el lado SE. Se trata de un canal medio excavado y medio construído que tiene su inicio en el centro del horno, entre las dos banquetas del fondo. Tiene una anchura de unos 10 cms. y una longitud de unos 60 cms. y desemboca en el pozo de escorias situado en el exterior.

Este pozo de escorias que, como el resto de estructuras, está medio construído y medio excavado en la roca, es prácticamente circular, con un diámetro aproximado de 60 cm y su profundidad oscila de momento entre los 10 y los 35 cms. El fondo de este pozo y del tramo final del canal de escorias está recubierto por una capa que podemos llamar de "tierra escoriada", formada por los restos de escorias que se han ido depositando y que se encuentran en un proceso de mineralización. La rugosidad de esta capa se corresponde con la superficie irregular de la cara inferior de las escorias coladas.

Por lo que hace referencia a la situación de los dos fuelles y de acuerdo con el espacio del que disponemos, podemos especular sobre su ubicación más probable justamente sobre la roca tocando al muro oeste. Como ya hemos señalado con anterioridad, la piedra ha estado aquí retocada para formar una plataforma con la inclinación apropiada para conectar con el inicio del canal de aire. La entrada del aire a los fuelles se abriría por encima de la cubeta de escorias, por lo que se aprovecharía el aire caliente, que sería insuflado dentro del horno, y con el cual se obtendría con mayor rapidez la temperatura deseada.

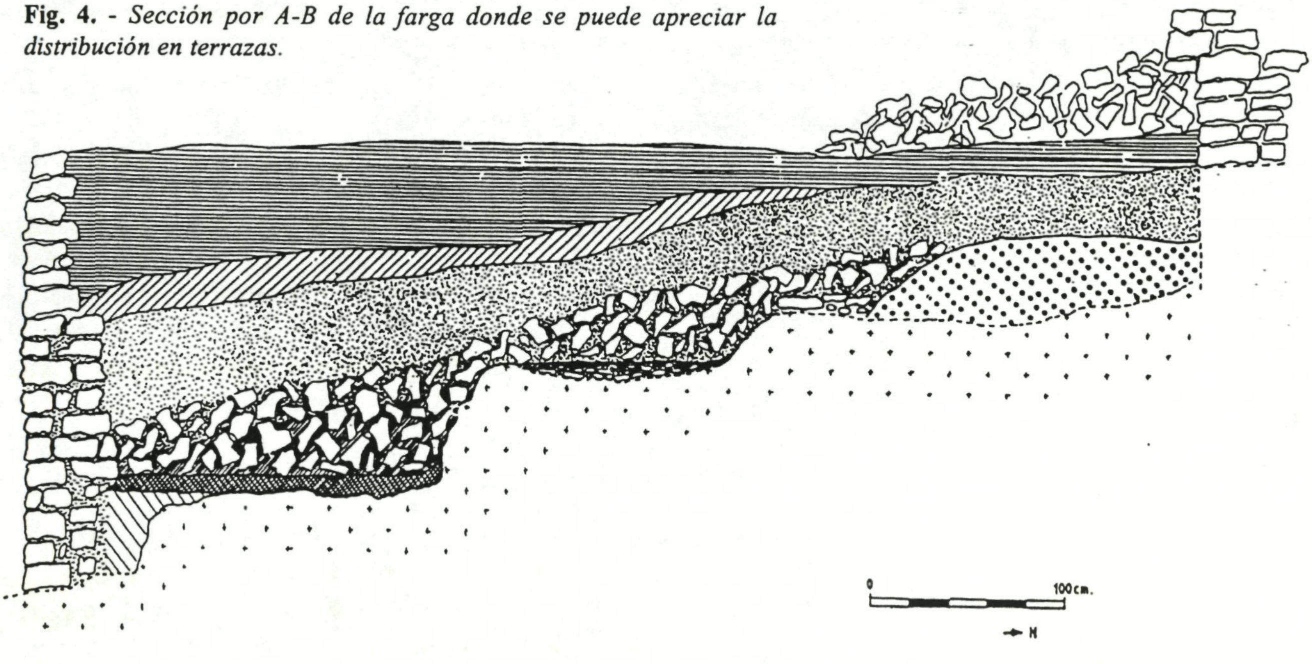
La analítica hasta ahora realizada en las escorias señala que la temperatura del horno tuvo que llegar a los 1300° C[4]. Estas temperaturas hicieron que las piedras que encontramos en el interior del horno tengan un color rojo intenso, además en el fondo del horno se encuentra tierra de silicio en abundancia, producto de la desintegración de las rocas que configuraban la estructura. Esta tierra presenta, según su grado de hidratación, dos tonalidades, una amarilla y otra más oscura, aunque los análisis han demostrado que se trata de la misma tierra. Los análisis realizados al mineral localizado en el interior del recinto de la *farga* revelan que se trata de goethita de gran calidad, con una riqueza en hierro del 40 al 80% .

El muro W de la *farga* limita por el exterior con una zona llana situada sobre el lecho del torrente que, en un primer momento, da la sensación de que se trata de un campo de cultivo. El hecho de que se encuentre en un tramo en el que el torrente presenta un desnivel considerable impide la existencia y formación de manera natural de este rellano. Esta observación nos condujo a realizar una prospección en este sitio que permitió observar la perfecta sedimentación en horizontal de una serie de estratos en una profundidad que llega, en el sitio prospectado, a 1,25 m.

Esta sedimentación tan solo puede haber sido provocada por la existencia en este sitio de una presa destinada a retener el agua para ser utilizada en el

[4] Los análisis realizados en el material férrico ha sido realizado por un equipo del Departament de Ciència de Materials i Enginyeria Metallúrgica de la Universitat Politècnica de Catalunya, bajo la dirección de la Dra. Júlia Simon i Arias, en colaboración con el Institut "Jaume Almera" del CSIC.

Fig. 4. - *Sección por A-B de la farga donde se puede apreciar la distribución en terrazas.*



funcionamiento de la *farga* . No se ha localizado hasta el momento ningún rastro de esta presa que, muy probablemente, debió haber sido de madera, pero esperamos poder llegar hasta el lecho de roca del torrente con tal de verificar la posible existencia de agujeros en la roca que nos indiquen su situación exacta y sus características.

Curiosamente la circulación del agua una vez colmatada y desaparecida la presa no ha hecho desaparecer el llano creado por dicha sedimentación ya que, tal y como hemos podido observar durante las estaciones más lluviosas, el agua se filtra por debajo de los sedimentos al entrar en este llano, saliendo por debajo de los estratos en su camino hacia abajo[5]. Los restos de esta presa por el agua situada al lado del edificio de la *farga* confirman el uso de la energia hidráulica, posiblemente para accionar un pequeño martillo pilón, tal y como parece indicar el gran encaje de más de 60 cms. de hondo y los dos pequeños encajes cuadrados, todos ellos situados en el sector sur del edificio. Este martillo facilitaría la operación de forja de la massa de hierro, una vez extraida del horno.

La producción de hierro

Enlazando con lo ya dicho, podemos señalar que la comunidad de pobladores de *Fabregada,* tenía como actividad principal la producción de hierro, la cual no se limita al proceso de reducción del mineral sino que incluye la extracción de mineral, la producción de carbón, el transporte de ambos hasta la *farga*, la elaboración del hierro a partir de la reducción y la forja y su posterior transformación en objetos de uso, mediante un segundo proceso de forja.

No disponemos de datos sobre la especializacióndentro de la propia comunidad, pero debemos suponer que existiría. Así mismo es posible imaginar una cierta estacionalidad de los distintos trabajos a realizados, determinados por las condiciones climáticas y naturales más oportunas.

Por ejemplo; la producción de carbón se concentraría principalmente en los meses de otoño, por ser estos los más adecuados para cortar la madera que será convertida en carbón. Así mismo, el funcionamiento de la *farga* estaría condicionado al caudal de agua disponible, por lo que se limitaría a los meses más lluviosos de primavera y otoño[6]. Esta propuesta de estacionalidad dejaría libres los meses de verano e invierno los cuales estarían dedicados a la extracción de mineral y a la confección de objetos para el uso.

Los trabajos siderúrgicos se alternarían con otras actividades productivas como la agricultura y la ganadería, aunque en ningún caso con la intensidad

[5] En los estudios del Dr. Francisco Burillo encontramos ejemplos de este tipo de evidencias que configuran y transforman el paisaje y que a menudo son difíciles de comprender e interpretar. Muchos de sus ejemplos tan sólo han conservado el testimonio de la existencia de los sedimentos de colmatación de una presa en los límites, ya que la circulación del agua se ha llevado la mayor parte de los sedimentos. Ver las actas de los diferentes *Coloquio de Arqueología Espacial* de Teruel.

[6] No dispoemos de datos muy precisos sobre la climatología propia del período estudiado, pero creemos posible que se produjera un cierto estiaje durante los meses más secos.

con que se realizarían en los otros lugares dedicados exclusivamente a estas actividades[7].

La extracción de minerales se realizaría en pequeños afloramientos superficiales, de fácil extracción, diseminados por la sierra del *Montsec.* Estos afloramientos suelen ser cavidades kársticas rellenas de óxidos de hierro depositados allí por la acción del agua. Estos óxidos de hierro procederían de los dos estratos ferruginosos localizados en la estructura geológica del *Montsec,* entre las calcareas y las margas de los niveles jurásicos y entre las calcareas del Cretacio Superior. Desconocemos el método de extracción y el número de afloramientos que pudieron ser explotados. Hasta el momento hemos podido localizar uno de estos yacimientos, pero no no deberemos avanzar en su estudio antes de obtener resultados fiables.

Los recursos minerales del *Montsec* por lo que se refiere a óxidos de hierro son muy limitados, por lo que su explotación sólo es posible dentro de una economía marcada por el autoabastecimiento. La localización y explotación de nuevos yacimientos debía ser cada vez más dificultosa, factor que jugaría un papel determinante en el cese de la actividad productiva y el posterior abandono del lugar.

La explotación de los recursos minerales no supondría graves problemas entre los distintos colectivos que habitaban el valle, ya que no se interfería con las otras actividades productivas como la agricultura o la ganadería. Así mismo, el carboneo propiciaba la deforestación de zonas que podían ser aprovechadas como pastos o incluso ser transformadas en terrenos agrícolas. En un principio no creemos que existieran conflictos por la explotación de estos recursos que, obligatoriamente se realizarían fuera de los términos estrcitos de *Fabregada,* en zonas de comunales o con el permiso y el pacto correspondiente con sus propietarios.

El transporte del mineral y del carbón se realizaría con animales de carga, por caminos de montaña más o menos acondicionados. Este transporte implica un enorme esfuerzo por el peso y volumenn de los materiales a transportar. Es por ello que pensamos en una posible selección del mineral en el mismo punto de extracción con lo que se reduciría la cantidad a transportar.

Respecto al proceso de reducción del mineral a hierro metálico, consideramos como lo más destacado de nuestra investigación, la localización de un horno alrededor del cual se ordena un espacio de trabajo concreto. Cabe la posibilidad de que hubiera más de un horno funcionando simultanea o alternativamente, aunque por el momento no podemos demostrarlo.

Teniendo en cuenta las estrcuturas localizadas y los análisis realizados en las paredes del horno, podemos confirmar que se trata de un horno bajo, de planta ovalada, con un diámetro máximo de 60 cm. y mínimo de 40cm, y una profundidad de 60 cm. Asociado a esta cámara de reducción, encontramos una entrada de aire forzado y una salida de escorias con un pozo de recogida en el exterior. La poca resistencia de la roca calcarea a las altas temperaturas, obligaría a revestir el interior de la cámara de reducción con una capa de arcilla, de la cual disponemos de algunas muestras localizadas en la misma intervención. Los analisis realizadas en las paredes interiores del horno confirman la existencia de este recubrimiento de arcilla que posiblemente sería substituido siempre que se considerara oportuno.

El proceso de reducción de mineral, se completaría con un trabajo de forja de la masa de hierro, destinado a compactar las partículas de metal y a expulsar los fragmentos de escoria que pudiera contener. Este forjado se realizaría con un mazo hidráulico de pequeñas dimensiones si lo comparamos con los grandes mazos de las *Fargas Catalanas* de época moderna. Debemos tener en cuenta que el volumen y peso de la masa de hierro sería, también, muy inferior al que producirían las instalaciones de época moderna.

La cronología que hemos podido determinar para el sector 100 y que se corresponde con la *farga,* viene determinada por los fragmentos de cerámica gris localizados en los niveles de fundamentación y destrucción del edificio, muy distintos de los que encontramos en los niveles de destrucción del poblado y que corresponden al s. XIII. Partiendo, pués, del material cerámico localizado en la *farga,* proponemos una fecha de construcción dentro del s.XI y de abandono durante el s.XII. Esto no implica que dejara de producirse hierro en esta fecha sino que, posiblemente se trasladaría a otro sector del poblado aún por excavar.

Partiendo de las características y capacidad del horno, la mas de hierro obtenida no superaría los 25 Kg. de peso, que sería transformado en una primera fase, en barras de diferentes calidades, tamaños y formas.[8]

---

7 En la cuarta campaña de excavaciones realizada en verano de 1995 en el sector del poblado, se han localizado pequeños pesos de telar que indican una cierta actividad textil.

8 El fragmento de perfil de hierro localizado en la segunda campaña sería uno de estos productos semi-acabados que produciría la *farga.*

Posteriormente, a partir de un trabajo de forja, se fabricarían objetos de uso de los que tenemos constancia por las piezas localizadas a lo largo de la intervención. No disponemos de datos sobre el taller de herrero ni de su situación dentro del conjunto o sus característiques. Esperamos poder localizarlo en futuras campañas.

Los residuos derivados de este proceso de fabricación, las escorias, se encuentran en el escorial, situado a unos centenares de metros del poblado. Así mismo hemos podido localizar algunas escorias en los alrededores del yacimiento, lo que nos indicaría la existencia de más de un escorial. Parece bastante lógico que existan distintas zonas acondicionadas para depositar estos residuos debido a la gran cantidad de estos deshechos que produce esta industria y a su continuidad en el tiempo, entre los siglos XI-XIII.

Los residuos o deshechos debían ser un grave problema debida su gran cantidad y su inutilidad o imposibilidad de reciclaje. Su transporte hacia una zona donde no suponga una molestia, podría estar ligado al recorrido de los transportistas de carbón y mineral, lo que explicaría la situación de los escoriales en el camino hacia las zonas boscosas. Desearíamos poder contrastar este aspecto en otras zonas donde se conserven restos de actividad siderúrgica.

Abandono de Fabregada

Documentalmente podemos afirmar que *Fabregada* ya no existía en el s. XIV, ya que no aparece en los *fogatjes* o censos de hogares, donde sí aparecen los otros pueblos del valle. A nivel arqueológico hemos podido confirmar la cronología de su abandono durante el s. XIII, ya que los materiales localizados en los niveles de destrucción, corresponden a este período.

Debemos suponer que *Fabregada* se abandona a lo largo del s.XIII como núcleo de hábitat y establecimiento de producción de hierro, aunque algunos de sus edificios fueron utilizados como huertos y corrales hasta mediados del s.XX.

Las razones de este abandono estaría propiciado por la interacción de múltiples causas. El progresivo agotamiento de los yacimientos de mineral, cada vez más difíciles de localizar en un medio donde son escasos, la falta de tierras de cultivo y pastos propios que permitieran un cambio de orientación en la actividad productiva de sus habitantes, y una mayor facilidad para acceder al hierro procedente de otras zonas productoras a través de un comercio en expansión, estarían en la base del despoblamiento del lugar.

Sus habitantes se desplazarían hacia los pueblos vecinos en busca de nuevas formas de vida. El topónimo se conserva por la perduración del culto a la *Virgen de Fabregada,* en la ermita que antes había sido iglesia y parroquia de la comunidad.

Proyectos de futuro

La continuidad de la investigación sobre *Fabregada,* pasa por cuatro aspectos concretos. En primer lugar por el estudio arqueológico del poblado y el escorial, con el fín de analizar el tipo de hábitat e intentar localizar otros materiales y estructuras que nos informen sobre la activiodad siderúrgica. El material procedente del poblado nos puede aportar una información muy interesante sobre la vida en este lugar y así poder establecer comparaciones con otros núcleos de hábitat medieval.

En segundo lugar, está previsto iniciar la prospección sobre el terreno para localizar puntos de extracción de mineral. Esta empresa presenta dos graves problemas: por un lado la dificultad que supone localizar pequeños yacimientos, diseminados en una amplia zona y que fueron intensamente explotados en la Edad Media, por lo que poco mineral visible se encontrará. Por otro lado, las profundas transformaciones que se han producido en grandes extensiones de la umbría del *Montsec,* provocadas por las repoblaciones forestales y los correspondientes aterrazamientos. Ello implica la necesidad de planificar esta fase con mucha precisión para concretar al máximo las prospecciones sobre el terreno.

En tercer lugar consideramos imprescindible iniciar el estudio sobre la evolución del paisaje, a través de análisis palinológicos y antracológicos, que nos permitan seguir las transformaciones de la cobertura vegetal y calibrar la incidencia de la presión humana, y en especial de la actividad siderúrgica, sobre el medio. En último lugar consideramos necesario continuar profundizando en el estudio de la dinámica de ocupación del valle en todos sus aspectos, con el fín de avanzar en el conocimiento más amplio de un proceso propio de la Cataluña medieval, como es el proceso de repoblación.

Bibliografía

FERNANDEZ DEL MORAL I. 1996: Organització del sistema defensiu medieval: La frontera del Montsec als volts de l'any 1000, en: Sancho *et. al.* 1996, 112-128.

GALLARDO A. & RUBIO S. 1930: *La Farga Catalana*, Rafael Dalmau Ed., Barcelona.

MASCARELLA J. 1993: *La Farga,* Quaderns de la Revista de Girona núm. 43, Girona.

MOLERA P. & BARRUECO C. 1983: *Llibre de la Farga,* Rafael Dalmau Ed., Barcelona.

NOLASCO N. 1996: Aproximació a l'estudi de les comunicacions de la vall de Sant Esteve de la Sarga:anàlisi de les fonts i definició d'una metodologia, en: Sancho *et al.* 1996, 98-111.

SANCHO M. 1994: La producció de ferro en època medieval al sud del Pirineu Català, en: *IV Congreso de Arqueología Medieval Española,* Asociación Española de Arqueología Medieval, Alacant, 899-904.

SANCHO M. 1995: *Arqueologia i documentació per a l'estudi de la producció de ferro en època Medieval; les fargues dels segles IX-XIII al sud del Pirineu Català,* Tesi Doctoal inèdita, Univ. de Barcelona.

SANCHO M. 1995: Les fargues medievals al sud del Pirineu. Recerca documental i arqueològica, en: Tomas 1995, 37-50.

SANCHO M., SIMON J., FDEZ DEL MORAL I. & NOLASCO N. 1996: *"Ipsa Fabricata"; estudi de la farga medieval de Fabregada (S.XI-XIII). Tres anys de recerques arqueològiques (1992-1994),* Universitat de Barcelona.

TOMAS E. (Coord.) 1995: *La farga catalana en el marc de l'arqueologia siderúrgica. Ier Simposi Internacional sobre la Farga Catalana. Ripoll 1993,* Govern d'Andorra, Andorra.

Marta Sancho i Planas
Grup de Recerca d'Arqueologia Medieval i Postmedieval
Departament d'Història Medieval, Paleografia i Diplomàtica
Universitat de Barcelona

Justine Bayley

Developments in metalworking during the medieval period

Innovations in metals technology in the later medieval period were coupled with greater craft specialisation and alterations to both the scale and organisation of production. Evidence for these changes can be found among the finds from British archaeological excavations and also in contemporary documentary sources.

Introduction

This is a brief review some of the available evidence for medieval metalworking from Britain. Archaeology is not our only source of information as technical treatises and surviving documents of other sorts are also useful in showing how and where craftsmen worked. The overall picture is complex, as there are significant differences between ironworking and non-ferrous metalworking, metal extraction and fabrication, urban and rural sites. This paper concentrates on non-ferrous metals and on evidence from towns, and hence deals mainly with metal fabrication.

From around the 13th century there were changes in the organisation of metalworking in Britain, with more centralisation of production and the setting up of guilds in towns to exercise control or protection. Metalworking crafts and industries were becoming more specialised, and much of the archaeological evidence for them is not as widespread as in earlier periods. Surviving medieval documents show there was a concentration of individual crafts in particular streets or areas in towns. This spatial concentration works in two ways: when archaeologists find a metalworking site they finds large quantities of material, but very often they find almost nothing.

In metallurgy, as in other ways, the later medieval period was one of considerable innovation; new technologies began to supplant those that had operated unchanged for more than a thousand years. Some of these introductions, and the reasons for their adoption, are also discussed. There were also changes in the scale of operation of the crafts and industries and in the types of objects being manufactured. Both these changes mean that the nature of the manufacturing debris that is found in the course of archaeological excavations has some notable differences from that of the earlier medieval period.

Alloy selection and use

Work by Cameron (1974), Brownsword and Pitt (e.g. 1983) and Blades (1995) has shown that the composition of the copper alloys used in the later medieval period was different from those of earlier times (e.g. Blades 1995; Bayley 1992a). Earlier medieval alloys tended to be either brasses (copper-zinc alloys) or bronzes (copper-tin) with relatively few mixed alloys. In later times the picture is different with zinc-rich gunmetal (copper-zinc-tin) with several percent of lead predominating for small cast objects. Wrought metalwork is very low in lead and much is again gunmetal, although a proportion is of high-zinc brass.

Larger castings have different compositions. Although church bells had been made from as early as the 10th century (Bayley *et al.* 1993), their typical composition of copper with 20-25% tin and a percent or two of lead did not evolve until the 12th century (*ibid.*, table 4). Cast cooking vessels did not become common until even later and were normally heavily leaded copper with a little tin and percentage levels of arsenic and/or antimony (Brownsword 1981; Blades 1995). This alloy is not a good one and its main advantage must have been low price. The copper that formed the bulk of the metal would have been smelted under strongly reducing conditions from polymetallic ores such as those found in the Harz mountains in Germany. If the metal had been purified the arsenic and antimony would have been removed and up to 10% of the metal yield would have been lost. The cast sheets which were engraved to make memorial brasses have a composition that much more closely mirrors that of the smaller objects. The copper may have come from similar sources to those used for the cast vessels, but it had been carefully refined to remove unwanted impurities before being alloyed. Over the period from the 13th-17th centuries the mean zinc content of memorial brasses rose from around 15% to 28% while tin content dropped from 5% to 1%; lead contents were variable in the range 2-5% (Cameron 1974).

Lead and pewter trinkets are known from the later 10th century (Bayley 1992a, fig 340) as are antler moulds for casting them (Newman 1993). However, from the 13th century a far larger range of trinkets, especially pilgrim badges and ampullae, become common. These were cast in piece moulds made of fine-grained lithographic stone, with lead pegs to correctly locate the two valves (e.g. Homer 1991, fig. 22). The solid badges were normally pewter while hollow ampullae were slush-cast from pure tin. Pewter vessels were cast from the late 13th century onwards and Homer (1991) suggests a range of mould materials were used, though bronze moulds were normal from the later 14th century.

Copper alloy casting

The size of crucibles used to melt copper alloys gradually increased through the medieval period. In the 10th-11th century they were typically globular and 60-80 mm in diameter, while by the 13th century shapes were more usually hemispherical and diameters had increased to up to 200 mm. From the 14th century deeper, thick-walled, flat-bottomed forms became common and continued in use into the 17th century and beyond (Bayley 1992b, fig. 5). Their diameters ranged up to about 180 mm and they would have held up to 10 kg of metal. The fabrics of these new types of crucible were also new ones. Instead of being sand-tempered like much domestic coarseware, they were far more refractory and so were much stronger at the high temperatures needed to melt metals. It was this increased strength which made the increase in size possible as the new crucibles could safely support the weight of a far larger amount of molten metal. In the post-medieval period graphitic clays were sometimes used to make crucibles of this form, a development that is still current today. Their advantage was in helping to ensure reducing conditions within the crucible and hence minimise metal losses into crucible slags.

The earlier, round-bottomed crucibles would have been stable when bedded into a charcoal fire, while flat bases suggest a changed hearth or furnace design, perhaps with a grid on which they sat. Agricola's *De re metallica* (Hoover & Hoover 1950) includes illustrations of a range of furnaces and hearths of this type, though they do not usually survive in archaeological contexts. One exception is a 16th century, brick-built hearth in Legge's Mount in the Tower of London which had associated with it a large number of crucibles and other metallurgical finds (Parnell 1993, fig. 40).

The larger crucibles indicate an increase in the quantity of metal being melted and cast, and mass-production of a sort was certainly practised, though perhaps not yet on the scale that became common during the Industrial Revolution. An example of this is the casting of multiple objects in a single composite mould. The products were strips of unfettled castings like some buckles from Coventry (Bayley & Wright 1987, fig. 49, nos 14-16); multi-piece stacked clay moulds for casting them are also known from Coventry (*ibid.*) and from London (Armitage *et al.* 1981).

Large clay moulds

In addition to the larger numbers of small copper alloy objects, increased availability of metal and growing technical competence led to the production of more large castings, especially from the 14th century onwards. There were two main groups of products, church bells and cooking vessels such as cauldrons and skillets.

The main evidence found for the production of these large castings are quantities of fired clay mould fragments, normally described as 'bell-mould' whatever the form of the casting. Often they are found backfilled into bell pits where the mould had stood while the molten metal was run down into it from a reverbatory furnace where it had been melted. Typically the mould fragments are 20-40 mm thick, oxidised-fired on the outside and reduced-fired inside, sometimes with a fine clay slip on the inner surface. The fabric contained a high proportion of vegetable temper (added to the clay as animal dung) which burnt out when the mould was fired, giving it a slightly porous structure. This was an advantage as it helped avoid trapped gases and hence blowholes in the casting, and also ensured that the mould was not too rigid. Metal castings contract as they cool, so in order to avoid cracking them the core of the mould either has to give as the metal shrinks or has to be removed while the casting is still hot. The special fabric was an elegant answer to this perennial problem.

If only small fragments of mould survive, it is not possible to reconstruct the form of the casting and in these cases the composition of adhering metal waste is the only indicator of the type of casting being made. This approach was used on the surviving material from the Bedern foundry site in York (Bayley & Richards 1993) where domestic vessels appear to have been the main products. In a few cases where the mould survives better it can be reconstructed and the way it was made identified. An example is a nearly complete cauldron mould from Prudhoe Castle, Northumberland (Wilthew 1986), where the outer part of the mould (cope) was divided vertically into two parts, and these had then been luted together and the rim sealed onto the core (inner part of the mould). The cauldron was cast upside down, probably by feeding the molten metal down one or more of its three feet.

Precious metal working

From the Roman period onwards there is evidence of precious metal assaying and refining as well as fabrication; the quality of the metal was always an important consideration (Bayley 1992c). Separating precious metals from base ones was achieved by cupellation. The metal to be refined was melted with an excess of lead; this was oxidised, forming litharge (lead oxide), which both oxidised any base metals present and dissolved these oxides, separating them from the silver or gold.

Small-scale cupellation was carried out on shallow dishes known as tests or cupels with diameters of 30-50 mm. Up to about the 12th century these cupels were always ceramics, some were purpose-made dishes but sherds from broken pots were used too. Bone ash was also used for making cupels because, unlike clays, it did not react with the litharge but absorbed it, providing better separation and thus more accurate assays. The earliest surviving bone ash examples are 16th-century finds from the Tower of London. There are no British archaeological finds for the intervening period so we do not know when the change took place, though Agricola and Ercker, both writing in the 16th century, describe bone ash as the normal material for cupels and thus probably not a recent innovation.

Parting, the separation of silver from gold, is the other precious metal refining process used in medieval times. Two solid-state processes are described by Theophilus (Hawthorne & Smith 1979) and Agricola (Hoover & Hoover 1950) but archaeological evidence for only one, the salt process, has yet been found (Bayley 1991a). This was of considerable antiquity and continued in use until at least the 13th century (Bayley 1991b). Around the 14th century a new process, acid parting, was developed. In this the silver in a gold-silver alloy was dissolved in nitric acid, separating it from the gold which was not affected. The production of nitric acid, by distilling vitriol with saltpetre, was a 14th century innovation but there is no evidence that the earliest finds of distillation-apparatus in Britain, which date to the 15th century, were used in this way (Moorhouse 1972). However, excavations on several 16th and 17th-century sites in London, including Legge's Mount, have produced ceramic cucurbits which were used in the production of nitric acid; most have superficial deposits of iron oxide, a by-product of the distillation of vitriol.

References

ARMITAGE K.H., PEARCE J.E. & VINCE A.G. 1981: A late medieval 'bronze' mould from Copthall Avenue, London, *Antiquaries Journal* 61(2), 362-364.

BAYLEY J. 1991a: Archaeological evidence for parting, in: E. PERNIKA & G.A. WAGNER (eds), *Archaeometry '90*, Basel, 19-28.

BAYLEY J. 1991b: *Evidence for metalworking from Pit 157, Site 25296, Thetford, Norfolk*, Ancient Monuments Laboratory Report 126/91.

BAYLEY J. 1992a: *Anglo-Scandinavian non-ferrous metalworking from 16-22 Coppergate*, Archaeology of York 17/7, London.

BAYLEY J. 1992b: Metalworking ceramics, *Medieval ceramics* 16, 3-10.

BAYLEY J. 1992c: Goldworking in Britain from Iron Age to medieval times, *Interdisciplinary Science Reviews* 17(4), 314-321.

BAYLEY J., BRYANT R. & HEIGHWAY C. 1993: A tenth-century bell-pit and bell-mould from St Oswald's Priory, Gloucester, *Medieval Archaeology* 37, 224-236.

BAYLEY J. & RICHARDS J.D. 1993: Medieval founding, in: J.D. RICHARDS, *The Bedern foundry*, Archaeology of York 10/3, York, 186-200.

BAYLEY J. & WRIGHT S.M. 1987: Metal working and miscellaneous finds, in: S.M. WRIGHT (ed), *Much Park Street, Coventry: the development of a medieval street. Excavations 1970-74*, Transactions of the Birmingham and Warwickshire Archaeological Society 92, 84-88.

BLADES N.W. 1995: *Copper alloys from English archaeological sites 400-1600 AD: an analytical study using ICP-AES*, University of London, unpublished PhD thesis.

BROWNSWORD R. 1981: On the compositions of some leaded bronze objects of the 14th and 15th centuries, *Medieval Archaeology* 25, 164-165.

BROWNSWORD R. & PITT E.E.H. 1983: Alloy composition of some cast 'latten' objects of the 15th/16th centuries, *Historical Metallurgy* 17(1), 44-49.

CAMERON H.K. 1974: Technical aspects of medieval monumental brasses, *Archaeological Journal* 131, 215-236.

HAWTHORNE J.G. & SMITH C.S. (trans) 1979: *Theophilus' On divers arts*, New York).

HOMER R.F. 1991: Tin, lead and pewter, in: J. Blair & N. Ramsay (ed), *English medieval industries*, London, 57-80.

HOOVER H.C. & HOOVER L.H. (trans) 1950: *Georgius Agricola's De re metallica*, New York.

MOORHOUSE S. 1972: Medieval distilling-apparatus of glass and pottery, *Medieval Archaeology* 16, 79-121.

NEWMAN J. 1993: *Three antler moulds from Ipswich*, Finds Research Group 700-1700. Datasheet 17.

PARNELL G. 1993: *The Tower of London*, London.

WILTHEW P.T. 1986: *Examination of mould from Prudhoe Castle, Northumberland*, Ancient Monuments Laboratory Report 4818.

Justine Bayley
Ancient Monuments Laboratory
English Heritage
23 Savile Row
London W1X 1AB
UK

Catherine Mortimer

Punching and stamping on Anglo-Saxon artefacts

Abstract

Although much smaller and more severely-limited by the method of manufacture, the design range used for punches on Anglo-Saxon metalwork overlaps with that used in pottery stamps of the period. Information from a study of punchmarks on metalwork is compared with interpretations of contemporary pottery stamps.

Introduction

Punchmarks on early Anglo-Saxon metal artefacts and stampmarks[1] on contemporary pottery have both been widely studied, from various points of view. Naturally, one of the most frequently considered aspects has been the typology or classification of the marks. Several previous studies have concentrated on trying to identify designs which belonged to a particular period, area or social group or individual punches/stamps which belonged to individual metalworkers/potters, but this is not the prime concern of this paper. The way that marks were laid out on the artefact has also been widely discussed, especially for pottery, but also for metalworking to a certain extent. Finally it has often been proposed that the use of both punchmarks and stampmarks had symbolic as well as decorative importance. This paper is an initial attempt to compare the design and employment of punches used on non-ferrous[2] metalwork with that of stamps used on pottery, as a first step towards considering such theories.

Designs

1 Metalwork

Punchmarked decoration is relatively commonly found on early Anglo-Saxon metalwork, although its prevalence and its nature seem to vary with artefact type, with region and with date. No overall survey of the tradition has yet been attempted, but there are a number of studies of the use of marks on particular artefact types (*eg* Ager 1985; Leigh 1980; Mortimer 1990). Now a study of marks on material from the 1989-1991 excavations at Barrington Edix Hill (BAEH), a cemetery site, set in its regional context (Mortimer & Stoney 1996), can be added to these works. BAEH can be taken as a typical early Anglo-Saxon cemetery, with a 'typical' range of artefact types, mostly dating to the sixth century.

At BAEH, 45 copper-alloy artefacts with punchmarks were examined and recorded in detail using silicon rubber impressions and a scanning electron microscope (SEM) mainly in backscattered electron mode. Images were recorded digitally, allowing accurate measurement of dimensions and angles. Technical details of the project are available elsewhere (Mortimer & Stoney 1996, Appendix) and the research of several other specialists was extremely helpful (*eg* Larsen 1987; Meeks 1988). The recording process was successful, providing startlingly clear images of the tiny marks, but it also proved time-consuming. Hence future work, especially on larger groups of material, needs to be carefully considered and as much information as possible must be gained from the project already completed. The BAEH

1 The difference between the terms 'punching' and 'stamping' may not be clear to a non-technical or a non-English audience. In this paper, punching will refer to the application of marks on metalwork and stamping to application on ceramics. In fact, stamping has equally been used in reference to metalworking. Generally speaking, punching normally implies a greater, and more sudden force was applied than for stamping, which could be thought of as closer to pressing or impressing.

2 Non-ferrous artefacts will be used in this study, and most of the commentary will be concerned with copper-alloy artefacts, rather than those of precious metals. Although iron objects of this period may have been punchmarked, it is much more difficult to study them due to their poor preservation.

material was compared with museum collections from nearby sites, excavated earlier this century or in the 19th century (Barrington A, Barrington B and Haslingfield) and with published material from two sites from Norfolk, Morning Thorpe (Green *et al* 1987) and Spong Hill – inhumation graves only (Hills *et al* 1984).

During the early Anglo-Saxon period, the range of punchmark designs that was used on metalwork is small compared with the design range seen in the pottery of the same period (see below). At individual sites, the range of designs seen is, not surprisingly, even smaller. Only 12 different punch designs were used on the 45 artefacts from BAEH (Fig. 1), although several artefacts were marked with more than one type of punch, or with two punches of the same design but of different sizes. The marks were generally small, mostly between 1 and 2 mm across their largest dimension. The smallest examples – as little as 0.78 mm across – were simple circular or oval dots. The larger punchmarks – up to *c.*5 mm across – were mostly the more complex designs, such as the ring-and-dot or double-ring-and-dot, but larger examples of the circular/oval form were also seen.

Previous researchers have tended to group together punchmark designs in the same way as they would any archaeological artefact. For example, most of the great square-headed brooches of Kent examined by Leigh (1980) had either circular (=ring-shaped) and triangular based forms (including those with internal detail). Few other designs were seen – a few semi-circular and one cross-shape – making classification relatively simple. During the study of the BAEH material, the method of making punches was examined and a new punchmark typology was proposed, with the highest level of classification based on the method of punch manufacture. In this typology, the marks were divided into five basic groups; a) solid geometric, b) solid, adapted from geometric, c) with punched additions, d) with filed/engraved internal divisions and e) with both punched and filed/engraved internal divisions. Circular, oval, triangular and rectangular marks are examples of Group a. Group b would include paired triangles, semi-circular or C-shapes, together with X, Z and S forms. To manufacture punches to make marks for both Groups a and b needed nothing more than a file and a good eye for close work, in order to complete the design. Group c includes ring, ring-and-dot and double semi-circular (double C or double U) forms. The method of manufacture for the punches to make these marks is perhaps less obvious, but it is immediately clear that they could not have been made using a file. To take the example of a ring punch, the tip would initially be fashioned so as to give a solid circular mark (as in Group a) and then, after annealing to soften the metal, a small circular depression would be sunk in the middle, using a further smaller circular secondary punch. If necessary, a file could be used to tidy up the circumference of the punch, if necessary. Punches to make the other Group c marks would be made in a similar fashion, using suitably shaped secondary punches. Theophilus (Hawthorne & Smith 1963) makes reference to the manufacture of punches in this way, in Book III, Chapter 18. Group d marks include triangles or other shapes with internal grids, as well as double Vs and Y-shaped marks with internal divisions. A fine-toothed file would be necessary to produce these designs. Group e marks are rare, and the only form seen in this study was 'broken rings' (ring marks with additional divisions, to make a negative cross). Material from the other cemetery sites examined have punchmarks which can be neatly fitted into this new typology. It is certain that the designs seen on the material from BAEH and the other cemeteries studied in this project are by no means the only ones used at this period. However, it is thought that any other types of mark still to be recorded would fit into one of the five groups of this punch manufacture-based typology.

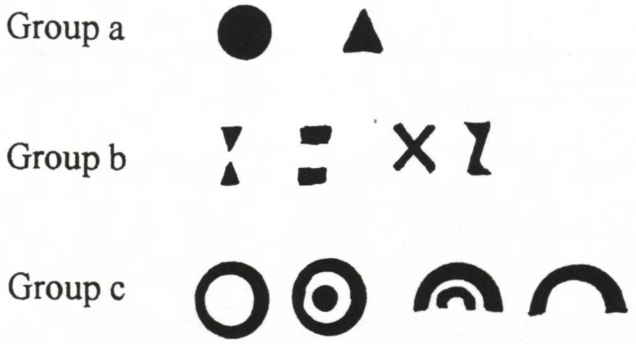


Fig. 1. - *Punchmark types found at Barrington Edix Hill 1989-1991 excavations (BAEH).*

Nearly all the designs commonly seen on metalwork are symmetrical, either around one or two axes. For example, circular, ring and ring-and-dot marks are symmetrical around two axes, and Vs, semi-circular and double semi-circular marks are symmetrical around one axis.

By far the most common punchmark Group at BAEH was Group a – 15 artefacts or pairs/sets of artefacts had Group a marks (all but one circular/oval), either on their own or with other designs (Table 1). The circular/oval marks were frequently used repoussé-fashion, that is to raise bumps or bosses on the front of an artefact, by pressing the punch from the back. Such marking was seen in many simpler forms of wrist clasp, where the sheet

Table 1
Punchmarks at Barrington, Haslingfield, Morning Thorpe and Spong Hill.
The table shows the number of times each punchmark type was found at the site (some artefacts had more than one type of punchmark on them, so this is not the same as number of artefacts); pair of sets of artefacts counted as one.

		Current site	Museum collections				Published sites	
		Barrington Edix Hill	Barrington	Barrington A	Barrington B	Haslingfield	Morning Thorpe	Spong Hill
group a	circular/oval repoussé	13		2		7	16	3
	circular/oval (non repoussé)	1	1	9		4	13	2
	solid triangular	1	2	1			10	
group b	V		4			1	7	1
	S						2	2
	Z	2						
	Y						3	
	Paired triangles/dots	1	1	1	6	1		
	Paired lines	1						
	X	1					2	
group c	semi-circular	3	7	6	9	4	21	3
	double semi-circular	3		1	4	8	23	6
	ring	1	4	4	8	2	47	16
	ring and dot		1			3	2	1
	double ring					1	1	
	double ring and dot	1	1					
	double semi-circular and dot						1	
	triangle with central dot	1					2	
	triangle with three dots inside	1	1				1	
group d	double V		3				4	3
	double lines						1	
	segmented Y			3	1		1	2
	grid in triangle			2	1		4	1
e	others (group e)						4	
	Totals	**31**	**25**	**29**	**29**	**31**	**165**	**40**

metal used was sufficiently thin to allow this to be carried out without piercing the metal – or at least not too frequently. Other designs were more rarely found, but double semi-circular, Z-shaped marks and semi-circular marks were found on more than one artefact. Ring marks were found on a pair of artefacts from a single grave.

It is interesting to note that double semi-circular punchmarks were found relatively frequently at BAEH and amongst collections from the neighbouring sites of Barrington A, Barrington B and Haslingfield. This is despite the difficulties envisaged in manufacturing the design at this small scale (the 'legs' of the design are between 1.2 - 1.5 mm apart) and it suggests that this particular motif was deemed important. At Morning Thorpe, the double semi-circular marks again seem to be popular, as they are seen on 23 artefacts out of a total of 165 instances of punchmarking. Ring marks[3] appear even more popular at Morning Thorpe and Spong Hill, where they are by far the most frequently used design; they were seen on 47 artefacts at Morning Thorpe and 16 (out of 40 instances of punchmarking) at Spong Hill. Ring marks were also the most popular design amongst the metalwork at Norton, Cleveland (Sherlock & Welch 1992, 56-7). Semi-circular and solid triangular punchmarks were common at Morning Thorpe.

Metalworking punches were also critical in brooch designs in Kent, although the dominant forms there were quite different. A brief survey of the punchmarked artefacts at Buckland, Dover, Kent (Evison 1987) shows that, of the punch types seen in the Anglian cemeteries, circular/oval dots, repoussé and otherwise (11 examples) and ring-and-dot (9 examples) are the most common designs, although neither design could be said to be frequently found. This largely reflects the types of artefact found. Particular artefact types which are often elsewhere found to be punchmarked, such as wrist clasps and annular brooches, were rarely or never seen at Buckland. Instead, many of the Buckland finds were brooches, of typical Kentish forms, such as silver-gilt disc brooches and square-headed brooches. These artefacts are still marked with punchmarks – those for niello settings (primarily long runs of small triangular marks along borders) and those used in notching (creating a beaded effect by marking the lines into short segments) – but these forms are normally classified and discussed separately to the other types of marks. These forms were also noted to be very common amongst the silver great square-headed brooches of Kent (Leigh 1980).

The majority of punchmarked artefacts have only one punch design, but the use of two or more types of mark is also relatively common, with the grander artefact types tending to have more, when they are punchmarked at all. For example, silver great square-headed brooches often have both notching and niello settings (and sometimes other types of punchmark) and larger cruciform brooch styles also tend to have notching, plus more than one other type of mark, where they are punchmarked at all (Mortimer 1990). In these studies on individual artefacts, it can be seen that the frequency and type of punchmark varies over time and geographically, so it must be expected that chronological and geographical variations will be seen in punchmark studies as a whole.

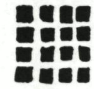
In the future, there should be more research on material from a range of Anglian sites and comparisons should be carried out between marks found on different types of artefact (particularly between copper-alloy, silver and gold artefacts), but this initial research does suggest that different punchmark designs were used at different sites. Similarly, further research should be carried out into seventh-century material, which a cursory survey seems to suggest it is less likely to be punchmarked than the sixth-century material.

2 Pottery

One of the most distinctive characteristics of early Anglo-Saxon pottery is its stamped decoration. From early on (*eg* Myres 1969; 1975), archaeologists have considered it important to record the marks in detail, primarily with the view of identifying stamps which were used on several different pots, which therefore must be the output of individual potters or workshops. The concentration on decoration generally, including that on pot stamps, initially led to the plain pottery of the period being rather overshadowed and under-represented in catalogues and discussions (*eg* Myres 1975). The reality is that stampmarked pots are in the minority in most sites, for example, at Mucking, only 11.7% of the cremation vessels were stamp-decorated (Richards 1987, 102) and 5% of the sherd groups from the settlement were decorated in any fashion (Hamerow 1993, 51). Recent approaches have improved this situation by looking at the vessel

[3] It is sometimes difficult to discern the difference between ring marks and simple dot marks when using publication drawings, since drawing conventions often make them look similar. Even with the object in the hand, the two types of punchmark can look similar, due to the problems of reflected light on shiny surfaces. For this paper, the author made the best guess possible on the basis of the drawings, but it would be preferable in future to examine the artefacts personally.

Fig. 2. - *The six most common types of stamp mark found on early Anglo-Saxon pots (after Briscoe 1983). A total of 3677 examples were recorded (Briscoe 1983, 71).*

Briscoe type	Shape	Number of instances
A4a		341
C2a		220
A1b		225
A5a		170
A2b		165
A3a		124

form first and then considering decoration schemes (*eg* Richards 1987). Nonetheless the pot stamps have been a very influential area of study.

Several typological approaches have been taken to the stamp marks, each with their own merits. This work has been primarily concentrated on the pottery from cremation cemeteries (urns), so this paper will concentrate on this sub-set of the early Anglo-Saxon record. Pottery from the Illington/ Lackford workshop was considered by Barbara Green and colleagues (Green *et al* 1981 (also used by Arnold 1983, 1988), the Spong Hill urns were studied by Catherine Hills and colleagues (*eg* Hills *et al* 1994), a separate classification was used in Julian Richards' study (Richards 1987) and the Briscoe's all-encompassing pot stamp project is still under way (Briscoe 1981, 1983). Each of these studies is concerned with the design of the stamp first and foremost. This is reasonable because manufacture of a stamp suitable for marking pottery was not particularly arduous. The materials used to make stamps were reasonably easy to work using a knife, file or small saw. Examples of bone and antler pot stamps have been found (Briscoe 1983, 58-9) and experience (Stokes 1984) shows that stamps made of these materials, of wood, or even of chalk, would have been perfectly practical in use. Thus manufacture of the stamps is not really an issue in the same way as it is for metalworking punches[4]. It is interesting however to note that Briscoe (1983, 59) states that 'each of [the] recorded dies would appear to be the work of an expert' although on what basis is not clear.

Pot stamps are much larger than metalworking stamps; for example, the smallest mark amongst the Illington/Lackford group was 4.9 mm in its largest dimension and the largest mark was 11.9 mm across (Arnold 1988). Stamps for more complex designs, such as animal motifs, are even bigger, between 40 and 50 mm in length.

Each of the classifications has stressed the huge variety in stamp designs and most of the studies have resulted in an extremely detailed classification, comprising many types and subtypes. When comparing the designs used on pots with those used on metalwork, the most noticeable feature is the sheer diversity and the frequency of asymmetric and non-geometric designs (especially the animal and runic motifs, but also spirals and swastikas). This diversity and elaboration is possible, of course, due to the much larger dimensions and the ease of stamp fabrication. The designs used on metalwork can be seen as a subset of those used on pots; so far no punchmark designs have been seen on metalwork that do not have their equivalent on pots.

4 If the animal motif marks were made with metal stamps, which seems possible, evidently these would have required far more complex manufacturing procedures.

The popularity of particular designs are not the same on pottery as on metalwork. Using the Briscoe classification (Briscoe 1983), the most common types of stampmark are A4a, C2a, A1b, A5a, A2b and A3a (Fig. 2). Of these, only A1b (rings) and A2b (double rings) are at all common on metalwork. Type A4a (positive cross in a circle) is particularly popular but has not yet been found on metalwork of the period, although one would have thought that its manufacture would not have been a challenge to the metalworkers who could for example fashion punches which gave double semi-circular designs.

Solid geometric designs (Groups a and b in the punchmark typology) are rarely found on pots. The prevalence of these designs amongst the metalwork may be due to the ease of the manufacture, which may have meant that such punches could be fashioned in an *ad hoc* fashion, when circumstances demanded, merely by filing down a suitable piece of iron, perhaps without even the need for controlled heating and quenching processes (tempering). This is particularly the case for repoussé work, where only the merest hint of the outline of the punch tip can be seen from the front of the artefact, and hence the metalworker could have 'made do' with rough and ready punches without compromising the finished design. In contrast, it seems to be the 'norm' that pot stamps would be anything but plain; the potential for elaboration was nearly always seized. Again, the majority of the pots (75%) have either one or two punchmarks (Richards 1987, 102-105).

Regional preferences, or at least differences between use frequency at individual sites, have been noticed. For example, 60% of the urns at the Illington cemetery were decorated with stamps, but the potters supplying this site also used fewer forms with circular and rectangular outlines than those at other sites in Richards' survey (*op cit*).

Myres (1969) suggested that stamped decoration had its greatest intensity of use in the sixth century. Recent studies, such as those at the settlement at Mucking, Essex (Hamerow 1993, 52), have broadly confirmed Myres' theories. Amongst the ceramic material found at the settlements at Mucking, although the overall amount of decorated pottery decreased in the sixth and seventh centuries, the proportion of this which was decorated with stamps increased.

Whereas metalworkers could have used their punches for other purposes (*eg* piercing and scoring/scribing), pot stamps appear to have no other use. However, as pot stamps would be most suitable for working on organic materials (perhaps as dies for marking cloth?), the poor survival rate of organics on archaeological sites may affect this observation. There is no equivalent in pottery for the repoussé work seen on metalwork. However, considerable relief is gained by the use of bosses and raised collars seen on many pots.

Layout

1 Metalwork

Punchmarks are normally found along the edges of artefacts, or along lines where edges 'should be' – for example, amongst cruciform brooches where the division between the central part of the headplate and the extended 'wings' of the headplate is not defined by a change in height, punchmarks were nonetheless frequently applied to where this division would have been. Occasionally, punchmarks are placed along the centre line of artefacts *eg* down the 'nose' of the animal head of a cruciform brooch. In some instances where punchmarks are placed other than in accordance with these principles, it seems this may have been the work of a less-skilled metalworker, as in the asymmetric, if enthusiastic use, of punchmarks on a cruciform brooch from Hornsea, held in the Yorkshire Museum (Mortimer 1990).

However, punched designs on precious metals may be exception to the rule, see for example, a silver pendant from Dover Buckland Grave 35 (Evison 1987, Fig 21), a pair of silver bracelets from Boss Hall, Ipswich (Scull forthcoming) and a scutiform pendant from Grave 70, Norton (Sherlock & Welch 1992, Plate 14); it is interesting to note that ring marks were used in each of these cases and that a late sixth-century or seventh-century date would be possible for each of these artefacts. Even the more humble artefact forms were sometimes selected for punchmarked designs which are unrelated to the outline of the artefact form, *eg* at Morning Thorpe, S-shaped punch marks are laid out in two concentric semi-circles within the rectangular shaped wrist clasps from grave 97 (Green *et al,* Fig 330).

The orientation of the punchmarks also tend to emphasise the edges of artefacts. In most cases, where the marks have a 'direction', for example, semi-circular or double semi-circular marks, the open ends of the mark (the 'legs' in the case of semi-circular and double semi-circular marks) are placed towards the edge of the artefact, normally at a distance approximately equal to the size of the mark itself. Some exceptions to this rule can again be attributed to inexperience on the part of the metalworker, as on a small-long brooch from Haslingfield, where a row of marks was begun by striking two marks in the wrong orientation, before the mistake was realised (Mortimer & Stoney 1996, 16-17).

Each punchmark on the BAEH material was placed separately. There rarely, if ever, seems to be deliberate overlapping of marks or any use of marks placed close together so as to make an extended design, as seen on some late Roman designs and the earliest phases of Germanic metalwork (see Ager 1985, Fig 15, nos 19-24 and 34-36).

One of the most striking features of the layout of punchmarks on metal artefact is that it is frequently executed in an erratic fashion. Punches were struck at many different angles (sometimes causing partial marks) and marks are often made at widely differing distances from each other, at a variety of different angles to the edge of the artefact or different distances from the edge. This irregularity is especially significant when the skills required in making the punches themselves is considered. This disparity led to the suggestion that punches may have been created by different (more skilled) metalworkers than those who applied them. However, the large number of different individual punches which are present at BAEH and surrounding sites (Mortimer & Stoney 1996, 20-21) shows that there was no difficulty in accessing the products of these highly-skilled metalworkers.

2 Pottery

Stamps are normally seen in combination with raised bosses, collars or incised (hand-drawn) lines which define the overall layout of the decoration on the pot. Stamps were used for emphasis, *eg* running parallel to collars or lines, to fill in areas defined by bosses, collars and lines, and occasionally to add extra detail to bosses (*eg* not just outlining bosses but also making crosses over them). Potentially there is a very wide variety of different designs which could have been produced in this fashion, but the most common are horizontal or vertical bands and triangular fields (Richards 1987, 179). Myres utilised the German terms *stehende Bogen (s*tanding arches) and *hängende Bogen* (swags) to describe some of the most commonly found designs (Myres 1975, 14-16). Stamps are rarely used on their own, without the decorative framework of bosses, collars and lines. When they are, they either mimic the shapes normally produced by incised lines *eg* triangular fields or horizontal lines, or, just occasionally, they are scattered in a seemingly random fashion (see *eg* Myres 1975, Figs 111-112). Thus the use of stamps mainly seem to be an adjunct to layouts which were already defined in some other way, which is comparable to the use of punches to emphasise edges of metal artefacts.

All decoration is concentrated on the upper part of the pot, which is the most visible portion, and this can be compared with the use of punches on the 'front' of artefacts. Despite this general pattern, some decoration has been noted on the reverse of cruciform brooches, including incised lines, as well as the occasional runic inscription (Mortimer 1990, 288). This brief survey did not find mention of stampmarks inside vessels, but it seems that this should be checked for.

Orientation and alignment of stamps is very varied – in some cases, the placement seems positively slapdash, but there are many examples where the placement is impressively neat (see *eg* the Illington/Lackford workshop (Myres 1975, Figs 349-355)). Evidently the large size of most stamps meant it would be relatively easy to place them accurately.

Symbolism

Several authors have tackled the subject of symbolism with respect to stampmarks on pottery; rather less attention has been given to punchmarks on metalwork. Arnold (1983) proposed a heraldic or totemic function, *ie* that particular marks or combinations of pot stampmarks represented family groups. Other aspects of social identity may be represented by the number of different stamp dies (Richards 1987, 197) although the layout of the stamped impressions and the total number of stamps probably has more to do with the individual potters' preferences (*ibid*). Various origins have been suggested for the symbols, particularly those to do with religion or ritual. Many of the designs with a circular outline may have connections with sun symbols seen on other artefacts, including those from earlier periods (Briscoe 1983, 59); similarly semi-circular or crescent symbols may represent the moon.

Any of these interpretations could be extended to punchmarks on metalwork. One might stress the religious/magical aspects, on the basis that the very small size of the marks on metalwork meant that they could not be seen by all and sundry, only by those wearing the artefact (or those very close to the wearer!). If the punchmarks are 'signalling' something, then they are doing it in the most discrete (secretive?) fashion possible. Even a metre away, the eye cannot 'read' the internal details of the punch designs – it will merely register that there are punchmarks on the artefact. On this basis, are punchmarks primarily of decorational importance, stressing the edges of artefacts, much as a fringe stresses the edge of a curtain? This seems unlikely because of the variety of forms seen (a circular shape would look similar to a ring-and-dot shape at a distance, but both shapes were used) and because the metalworkers went to considerable trouble to fashion some of the designs (especially Group c, d and e forms), whilst ignoring some of the other designs known to potters which could also have been transferred to the metalworking environment. Hence it seems that there was more to punchmarks than mere decoration.

If marks on early Anglo-Saxon artefacts are symbolic, then the differences in motif prevalence for pottery and metalwork must be further explored. We have no reason to suppose that metalworkers could not produce punches with designs which were smaller versions of the most popular designs seen on pot stamps – after all, they produced other motifs which were at least as challenging – so why didn't they do so? It is presumably largely irrelevant that potters and metalworkers might have worked in different workshops, since in both cases, the artefacts produced are, in a sense, displayed items. However, the potters' product and hence the symbols on them, would be only 'exposed' on the burial day (assuming that cremation urns were not displayed on the mantelpiece as they are today) but the metalworkers products could be worn frequently or everyday. Hence the difference in motif preference between the pottery and the metalwork may be due to different symbolic 'requirement'. Did the potters' products have more of a function in public 'signalling', perhaps about the dead person's social grouping, whereas the metalworkers' products were more to do with the wearer's preferences or religious principles – did the punchmarks perhaps have amuletic connotations? The fact that runic inscriptions are displayed on the outside (the public side) of urns, but on the 'inside' (the back) of brooches, may also be relevant here. Alternatively, were the punchmarks used just the metalworkers own personal mark – a 'maker's mark'? Such aspects deserve more consideration and they will be the main topics of discussion during the presentation of this paper.

Acknowledgements

The Barrington Edix Hill excavations were carried out by Tim Malim of the Field Unit of Cambridgeshire County Council. Tim Malim, with the assistance of John Hines (University of Wales, Cardiff), is writing up the finds for the excavation publication. John Hines recorded and took the silicon rubber peels from the Barrington A, Barrington B and Haslingfield artefacts from the museum collections at the Cambridge University Museum of Archaeology and Anthropology and at the Ashmolean Museum, Oxford. Martin Stoney (on placement from Bradford University, Department of Archaeological Sciences) took many of the SEM photos on which the initial BAEH report was based. Technical study of the BAEH punchmarks was carried out at the Ancient Monuments Laboratory, English Heritage.

References

AGER B. 1985: The smaller variants of the Anglo-Saxon quoit brooch, *Anglo-Saxon Studies in Archaeology and History* 4, 1-58.

ARNOLD C.J. 1988: Early Anglo-Saxon pottery of the 'Illington-Lackford' type, *Oxford Journal of Archaeology* 7.3, 343-359.

BRISCOE T. 1981: Anglo-Saxon pot stamps, *Anglo-Saxon Studies in Archaeology and History* 2, 1-36.

BRISCOE T. 1983: A classification of Anglo-Saxon pot stamp motifs and proposed terminology, *Studien zur Sachsenforschung* 4, 57-71.

EVISON V.I. 1987: *Dover: The Buckland Anglo-Saxon cemetery*, Historic Buildings and Monuments Commission for England Archaeological Report 3.

GREEN B., MILLIGAN W.F. & WEST S.E. 1981: The Illington/Lackford workshop, in: EVISON V.I. (ed), *Angles, Saxons and Jutes; essays presented to J N L Myres*, Clarendon Press, Oxford, 187-226.

GREEN B., ROGERSON A. & WHITE S.G. 1987: *The Anglo-Saxon cemetery at Morning Thorpe, Norfolk*, East Anglian Archaeology 36.

HAMEROW H. 1993: *Excavations at Mucking, Volume 2: the Anglo-Saxon settlement*, English Heritage Archaeological Report 21.

HAWTHORNE J.G. & SMITH C.S. (trans) 1963: *On Divers Arts; the treatise of Theophilus*,University of Chicago Press.

HILLS C., PENN K. & RICKETT R. 1984: *The Anglo-Saxon cemetery at Spong Hill Part III: Catalogue of inhumations*, East Anglian Archaeology 21.

HILLS C., PENN K. & RICKETT R. 1994: *The Anglo-Saxon cemetery at Spong Hill Part V: Catalogue of cremations, nos 2800-3334*, East Anglian Archaeology 67.

LARSEN B. 1987: SEM identification and documentation of tool marks and surface textures on the Gundestrup cauldron, in: J. Black (ed), *Recent advances in the conservation and analysis of artifacts*, 393-407.

LEIGH D. 1980: *The square-headed brooches of sixth-century Kent*, Unpublished PhD thesis, University of Wales, Cardiff.

MEEKS N. 1988: Backscattered electron imaging of archaeological materials, in: S.L. OLSEN (ed), *Scanning electron microscopy in archaeology*, B.A.R. Int. Series 452, 23-44.

MORTIMER C. 1990: *Some aspects of early medieval copper-alloy technology, as illustrated by a study of the Anglian cruciform brooch*, Unpublished DPhil thesis, Oxford.

MORTIMER C. & STONEY M. 1996: *Decorative punchmarks on non-ferrous artefacts from Barrington Edix Hill Anglo-Saxon cemetery 1989-1991, Cambridgeshire in their regional context*, Ancient Monuments Laboratory Report 62/96.

MYRES J.N.L. 1969: *Anglo-Saxon pottery and the settlement of England.*

MYRES J.N.L. 1975: *A corpus of Anglo-Saxon pottery of the Pagan Period*, Cambridge University Press.

RICHARDS J.D. 1987: *The significance of form and decoration of Anglo-Saxon cremation urns*, B.A.R. 166.

SCULL C. forthcoming: *The Anglo-Saxon cemeteries of Boss Hall and Buttermarket, Ipswich.*

SHERLOCK S.J. & WELCH M. 1992: *An Anglo-Saxon cemetery at Norton, Cleveland*, Council for British Archaeology Research Report 82.

STOKES M.A. 1984: Anglo-Saxon pottery and die-stamps: preliminary notes on a programme of experimental archaeology, *Medieval Ceramics* 8, 27-30.

Catherine Mortimer
16 Norfolk Street
YORK 402 IJY
UK